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THE

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ASSISTED BY A COMMITTEE OF COUNCIL.

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1912.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 21, 1911, *at* 5 *p.m.*

Professor W. J. Lewis, M.A., F.R.S., President, in the Chair.

The audited balance-sheet for the year ending December 31, 1910, was approved.

A proposal to reprint Nos. 19 and 22 of the Journal, of which the stock is exhausted, was considered, and the Editor was instructed to report on the matter at the next meeting of the Council.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 21, 1911, *at* 5.30 *p.m.*

Professor W. J. Lewis, M.A., F.R.S., President, in the Chair.

Thirty-two Members and two Visitors were present.

The following papers were read:—

1. On Mr. Solly's observation of Wiltshireite in 1903: by Prof. W. J. Lewis (p. 197).

2. Two new minerals from the Binnenthal: by Mr. R. H. Solly.

3. Notes on Cassiterite in the Malay Peninsula: by Mr. J. B. Scrivenor (p. 118).

4. Notes on the occurrence of Dundasite in Derbyshire and Co. Galway, and of Bertrandite in Cornwall: by Mr. A. Russell.

5. On Quartz-twinning: by Dr. J. Drugman (p. 112).

6. Crystallographic notes: by Mr. T. V. Barker (p. 207).

Mr. Hutchinson exhibited a convenient form of apparatus for optic observations in monochromatic light.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 13, 1911, *at* 5 *p.m.*

Professor W. J. Lewis, M.A., F.R.S., President, in the Chair.

The deaths of Prof. N. Story-Maskelyne and Mr. John Woodgate were announced, and the President was requested to send a message of condolence to Mrs. Story-Maskelyne.

Resolved to nominate Messrs. W. Barlow, T. Crook, G. F. Herbert Smith, and Sir T. H. Holland in place of the four retiring members of Council (Messrs. G. Barrow, F. N. A. Fleischmann, H. Hilton, and A. Hutchinson).

Mr. Spencer reported that he has prepared on behalf of the Society 844 slips relative to mineralogical, crystallographical, and petrographical papers and books published in the United Kingdom during 1910, for the International Catalogue of Scientific Literature.

The question of reprinting Nos. 19 and 22 of the Journal was postponed.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 13, 1911, *at* 5.30 *p.m.*

Professor W. J. Lewis, M.A., F.R.S., President, in the Chair.

Twenty-six members were present.

The following papers were read:—

1. On Zirkelite from Ceylon: by Mr. G. S. Blake; with notes on the crystallography of the mineral, by Dr. G. F. H. Smith, and on the chemical composition, by Dr. G. T. Prior.

2. Note on some crystals of artificial Gypsum: by the Rev. Mark Fletcher (p. 137).

3. The larger Diamonds of South Africa: by Mr. L. J. Spencer (p. 140).

4. Brecciation in mineral-veins: by Mr. F. H. Butler (p. 124).

5. On Prehnite from the Lizard District: by Mr. A. Russell (p. 217).

Specimens were exhibited in illustration of the papers by Messrs. Fletcher, Butler, and Russell.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 14, 1911, *at* 5 *p.m.*

Professor W. J. Lewis, M.A., F.R.S., President, in the Chair.

Mr. Herbert Gladstone Smith was elected an Ordinary Member of the Society.

The death of Prof. Michel Lévy, an Honorary Member, was announced.

Principal H. A. Miers was appointed a Trustee of the Society in place of the late Prof. N. Story-Maskelyne.

The following were selected as the dates of meeting for the year 1912: Tuesdays, January 23, March 12, June 18, and November 12, the last to be the Anniversary Meeting.

The draft Annual Report of Council, submitted by the Secretary, was approved.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 14, 1911, *at* 5.30 *p.m.*

Professor W. J. Lewis, M.A., F.R.S., President, in the Chair.

Twenty-seven Members and six Visitors were present.

The election of Mr. H. G. Smith to the Ordinary Membership was confirmed.

The scrutineers reported that forty-four voting-papers had been returned, and that the list as nominated by the Council was approved, namely:

President. Prof. W. J. Lewis, M.A., F.R.S.
Vice-Presidents. Prof. H. L. Bowman, M.A., D.Sc., F.G.S.
A. E. H. Tutton, M.A., D.Sc., F.R.S.
Treasurer. W. Phipson Beale, K.C., M.P., F.G.S., F.C.S.
General Secretary. G. T. Prior, M.A., D.Sc., F.G.S.
Foreign Secretary. Prof. W. W. Watts, M.A., Sc.D., F.R.S.
Editor of the Journal. L. J. Spencer, M.A., F.G.S.

Ordinary Members of Council.

T. V. Barker, M.A., B.Sc., F.C.S.
W. Barlow, F.R.S.
J. H. Collins, F.G.S.
T. Crook, A.R.C.Sc.I., F.G.S.
C. G. Cullis, D.Sc., F.G.S.
J. W. Evans, LL.B., D.Sc., F.G.S.
Rev. J. M. Gordon, M.A., F.G.S.
Sir Thomas H. Holland, K.C.I.E., D.Sc., F.R.S.
J. A. Howe, B.Sc., F.G.S.
R. Pearce, Ph.D., F.G.S.
G. F. Herbert Smith, M.A., D.Sc., F.G.S.
H. H. Thomas, M.A., B.Sc., F.G.S.

The following Annual Report of Council was read:—

During the Session 1910–11 four meetings have been held (by kind permission) in the Apartments of the Geological Society, Burlington House, W., at which nineteen papers were read. Two numbers of the Journal (No. 73 published in May, and No. 74 in October) have been issued. In these numbers are published eighteen papers, twenty-one reviews, and a new list of the members of the Society. For the blocks for the plates of twenty-one figures of brecciated vein-stones in No. 74, the Society is indebted to Mr. F. H. Butler; and for the block for the figure of the universal goniometer in the same number, to Dr. Hutchinson.

The balance-sheet of the year ending December 31, 1910, shows the satisfactory financial position of the Society. The assets (exclusive of

the Library and stock of the Journal) amounted to £804 1*s.* 11*d.* and the liabilities to £12 15*s.* 9*d.* The value of the Stock invested in the names of the trustees of the Society was on that date £721 6*s.*, corresponding to £13 12*s.* 2*d.* for each Life-Member.

During the Session 1910–11 the Society has lost by death one Honorary Member, Prof. Michel Lévy, and two Ordinary Members, one of whom, Prof. Nevil Story-Maskelyne, was President of the Society for 1891–8. Four Ordinary Members have been elected. The total number of members on November 13, 1911, was 136; of whom eighteen are Honorary. Of the Ordinary Members, fifty-three have compounded for their annual subscription.

The Council has to congratulate the Society on its continued prosperity.

On the motion of Mr. Fleischmann, seconded by Dr. Hutchinson, the Report was adopted.

A vote of thanks to the Council of the Geological Society for permission to meet in the Apartments of the Society was carried.

The dates of meeting for 1912 proposed by the Council were approved.

The following papers were read:—

1. On crystals of Dufrenoysite and Seligmannite: by Mr. R. H. Solly.

2. A simple graphic method for determining extinction-angles in sections of biaxial crystals: by Mr. H. G. Smith (p. 232).

3. On a meteoric stone which recently fell in Egypt: by Dr. G. T. Prior.

4. Strüverite from the Federated Malay States: by Mr. T. Crook and Mr. S. J. Johnstone (p. 224).

5. On a total-reflection diagram: by Dr. A. Hutchinson (p. 236).

6. The occurrence of Ankerite in coal: by Mr. T. Crook (p. 219).

7. On the temperature at which Gypsum becomes optically uniaxial: by Dr. A. Hutchinson.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, January 23, 1912, *at* 5 *p.m.*

Professor W. J. Lewis, M.A., F.R.S., President, in the Chair.

Mr. Miles Burkitt was elected an Ordinary Member of the Society.

The resignations of Prof. W. J. Sollas and Mr. E. G. J. Hartley were accepted.

The deaths of Prof. G. Spezia and Dr. E. Hussak, Ordinary Members,

were announced. The Foreign Secretary was requested to send a message of condolence to Mrs. Hussak.

Dr. J. W. Evans and Mr. F. N. A. Fleischmann were elected Auditors of the accounts of the year ending December 31, 1911.

Mr. F. N. A. Fleischmann was appointed a Trustee of the Society in addition to Dr. R. H. Scott and Sir Henry A. Miers.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 23, 1912, *at* 5.30 p.m.

Professor W. J. Lewis, M.A., F.R.S., President, in the Chair.

Twenty-eight members were present.

The election of Mr. Miles Burkitt to the Ordinary Membership of the Society was confirmed.

The following papers were read:—

1. The relationship between crystalline form and chemical constitution: the double chromates of the alkalis and magnesium: by Miss M. W. Porter and Dr. A. E. H. Tutton (p. 169).

2. On a mineral possibly identical with Liveingite: by Prof. W. J. Lewis.

3. A new anorthic mineral from the Binnenthal: by Mr. R. H. Solly and Dr. G. F. H. Smith.

4. On Colemanite and Neocolemanite: by Dr. A. Hutchinson (p. 239).

5. Further observations on the optical characters of Gypsum: by Dr. A. Hutchinson and Dr. A. E. H. Tutton.

6. Note on a large crystal of Anatase from the Binnenthal: by Dr. G. F. H. Smith.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 12, 1912, *at* 5 *p.m.*

Dr. A. E. H. Tutton, M.A., D.Sc., F.R.S., Vice-President, in the Chair.

The audited balance-sheet for the year ending December 31, 1911, was approved, and instructions given for it to be published in the next issue of the Journal.

Mr. Clarence Roe Gardiner was elected an Ordinary Member of the Society.

BALANCE SHEET.

DECEMBER 31, 1911.

LIABILITIES.	£	s.	d.
Owing for Editor's Honorarium (1911)	10	10	0
,, G. Savigar for care of stock of Publications (1911)	1	1	0
,, Do. for postage (1911)		6	1
,, Hon. Secretary for postage (1911)		5	8
,, Hon. Treasurer ,, ,, (1911)		9	5
,, Williams & Strahan for Printing, &c.	1	19	4
Excess of assets over liabilities	779	7	2
	£793	18	8

ASSETS.	£	s.	d.	£	s.	d.
Balance at Bank	35	2	2			
,, in Office		2	4			
				35	4	6
Consols (£928 1*s.* 10*d.*, valued at £77½)				714	11	2
Sale of Publications—						
Owing from Publishers	37	6	0			
,, G. Savigar	1	12	0			
				38	18	0
Arrears of Subscriptions (estimated good)				5	5	0
				£793	18	8

The number of Life Members on December 31 was fifty-three.

The stock of Publications and the value of the Library are not included in the above assets. (*Signed*) W. P. BEALE,
Hon. Treasurer.

THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 75. MAY, 1912. Vol. XVI.

Crystallographic constants and isomorphous relations of the double chromates of the alkalis and magnesium.

By A. E. H. Tutton, M.A., D.Sc., F.R.S. and Mary W. Porter.

[Read January 23, 1912.]

THE interesting results which have followed the investigation by one of us [1] of the isomorphous series of double sulphates and selenates of the general formula $R'_2M''[(S, Se)O_4]_2.6H_2O$ have led us to extend the investigation to the corresponding double chromates in which M is represented by magnesium.

The ammonium salt, $(NH_4)_2Mg(CrO_4)_2.6H_2O$, was investigated by Murmann [2] and shown to belong to the monoclinic series in question. An analogous potassium salt was not obtained, the only known double chromate of potassium and magnesium crystallizing with two molecules of water, and therefore in an entirely different form, of triclinic pinakoidal

[1] A. E. H. Tutton, Journ. Chem. Soc., 1893, vol. lxiii, p. 337; 1896, vol. lxix, p. 344; 1905, vol. lxxxvii, p. 1123; Proc. Roy. Soc., 1900, vol. lxvi, p. 248; 1900, vol. lxvii, p. 58; 1910, ser. A, vol. lxxxiii, p. 211; Phil. Trans. Roy. Soc., 1901, ser. A, vol. cxcvii, p. 255.

[2] A. Murmann, Sitzungsber. Akad. Wiss. Wien, 1858, vol. xxvii (Jahrg. 1857), p. 175.

symmetry.[1] The rubidium and caesium salts of the series have recently been prepared by Barker,[2] and proved by a few goniometrical measurements, of azimuth and polar distance with the two-circle goniometer, to belong to the monoclinic series, and by chemical analyses to contain six molecules of water of crystallization. No optical measurements were made, these, as well as fuller goniometrical details, being by friendly arrangement left for the present authors to carry out with the special equipment described in previous memoirs and books.[3]

As regards the ammonium salt, Murmann mentions that the plane of the optic axes is the symmetry-plane for green light but perpendicular thereto for red light, this salt being thus another example, from this series, of crossed-axial-plane dispersion of the optic axes. Determinations of the specific gravity of this salt were also made by Abbot.[4]

These three salts—the ammonium, rubidium, and caesium—which we have investigated in detail, form excellent crystals, well suited for goniometrical and optical measurements. Caesium magnesium chromate is the most stable, no tendency to efflorescence being observed, even ground plates and prisms maintaining their surfaces unimpaired for a considerable time. The rubidium salt is less stable, and ground surfaces rapidly deteriorate, even, after a few weeks, when covered with cemented micro-cover-glass plates. Attempts to prepare the corresponding potassium salt were unsuccessful.

Ammonium Magnesium Chromate, $(NH_4)_2Mg(CrO_4)_2.6H_2O$.

An estimation of magnesium in confirmation of identity and purity, made with clear crystals of one of the crops investigated, yielded the following result: 1·1512 grams of crystals gave 0·3360 gram of magnesium pyrophosphate, which corresponds to 6·31 per cent. of magnesium, the calculated amount being 6·06 per cent.

Goniometry.

Crystal system: Monoclinic, holohedral, prismatic. (Class 5.)

Axial ratios and angle: $a : b : c = 0{\cdot}7517 : 1 : 0{\cdot}4924$; $\beta = 106° 7'$.

[Murmann's values, $0{\cdot}7511 : 1 : 0{\cdot}4931$; $\beta = 106° 31'$.]

[1] G. Wyrouboff, Bull. Soc. franç. Min., 1891, vol. xiv, p. 253.

[2] T. V. Barker, Journ. Chem. Soc., 1911, vol. xcix, p. 1326.

[3] A. E. H. Tutton, 'Crystalline structure and chemical constitution,' 1910; and 'Crystallography and practical crystal measurement', 1911.

[4] F. W. Clarke, 'Table of specific gravities,' Smithsonian Miscell. Collect., 1888, No. 659, p. 104.

Forms observed: $b\{010\}$, $c\{001\}$, $p\{110\}$, $q\{011\}$, $r'\{\bar{2}01\}$, $o\{111\}$, $o'\{\bar{1}11\}$.

Cleavage: $r'(\bar{2}01)$, excellent. Colour: Yellow.

Habit: Short prismatic, or tabular parallel to $c\{001\}$.

The b-faces were always well developed, and sometimes very large, and invariably gave good single images of the signal. The c-faces were large but often striated, giving multiple images, a similar observation also applying in a lesser degree to the p-faces. In the dozen crystals chosen for measurement, from very numerous crops, such striation was at its minimum, and no images were taken into account involving the phenomenon. The q-faces were also large and gave good images. The r'-faces were small, but yielded satisfactory images, one of the two faces being usually more developed than the other. Faces of the forms o and o'

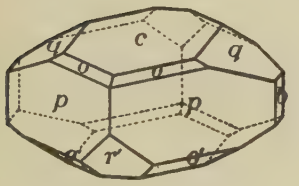

Fig. 1.

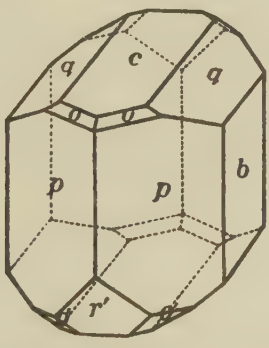

Fig. 2.

Crystals of ammonium magnesium chromate.

were not always present, and the images were rarely very good. No faces of the orthopinakoid $a\{100\}$ were observed, nor were any faces of the hemipyramid $n'\{12\bar{1}\}$ observed by Murmann ever found. The crystals were sometimes tabular parallel to $b\{010\}$, or more often to $c\{001\}$, and sometimes elongated along the b-axis with one pair of p-faces more largely developed than the other. The face grown in contact with the crystallizing vessel was either b, p, or c; such faces were usually free from striation and afforded excellent trustworthy images, although they showed contour depressions. Two actual crystals from different crops are represented in figs. 1 and 2.

Morphological Angles observed on Ammonium Magnesium Chromate.

Angle.	No. of measurements.	Limits.	Mean observed.	Calculated.*	Murmann's observed values.
$cr' = (001):(\bar{2}01)$	15	63°11′ – 63°26′	63°18′	63°11′	63°32′
$r'c = (\bar{2}01):(00\bar{1})$	15	116 34 – 116 48	116 42	116 49	...
$pb = (110):(010)$	32	53 59 – 54 16	54 10	*	54 14
$pp = (110):(1\bar{1}0)$	20	71 34 – 71 47	71 41	71 40	71 31
$pp = (110):(\bar{1}10)$	20	108 13 – 108 26	108 19	108 20	108 29
$cq = (001):(011)$	35	25 6 – 25 27	25 17	25 19	25 15
$qb = (011):(010)$	35	64 33 – 64 49	64 41	*	...
$co = (001):(111)$	2	33 31 – 33 48	33 39	33 40	33 47
$op = (111):(110)$	2	43 17 – 43 19	43 18	43 20	...
$cp = (001):(110)$	37	76 49 – 77 7	77 0	*	...
$po' = (110):(11\bar{1})$	8	59 0 – 59 7	59 2	59 6	59 12
$o'c = (11\bar{1}):(00\bar{1})$	6	43 46 – 43 59	43 55	43 54	44 28
$pc = (110):(00\bar{1})$	34	102 50 – 103 6	102 59	103 0	...
$bo' = (010):(\bar{1}11)$	5	65 17 – 65 24	65 20	65 22	...
$o'o' = (\bar{1}11):(\bar{1}\bar{1}1)$	3	49 17 – 49 23	49 19	49 15	...
$qp = (011):(\bar{1}10)$	29	87 11 – 87 27	87 19	87 19	...
$pq = (\bar{1}10):(0\bar{1}\bar{1})$	29	92 32 – 92 44	92 41	92 41	...
$qp = (011):(110)$	29	62 52 – 63 8	63 0	63 1	...
$pq = (110):(0\bar{1}\bar{1})$	30	116 54 – 117 8	116 59	116 59	...
$r'o' = (\bar{2}01):(\bar{1}11)$	6	34 56 – 35 5	35 1	34 57	...
$o'p = (\bar{1}11):(110)$	8	91 25 – 91 33	91 30	91 28	...
$pr' = (110):(20\bar{1})$	32	53 22 – 53 39	53 30	53 35	53 35
$r'p = (\bar{2}01):(110)$	30	126 17 – 126 37	126 28	126 25	...

* For the complete series of calculated angles for comparison, see the table on p. 189.

Volume.

Two series of determinations of specific gravity were made, with a dozen of the most perfect small crystals in each case, by the Retgers immersion method, using a mixture of methylene iodide and benzene. The heaviest crystals in the two cases afforded the following results:

For 19·0°/4°..... 1·8318..... For 20°/4°..... 1·8316.
„ 18·8°/4°..... 1·8321..... „ „ ..... 1·8319.

The value accepted for the density[1] of ammonium magnesium chromate at 20°/4° is accordingly 1·832; from which are calculated the molecular volume, $\frac{M}{d} = \frac{397{\cdot}46}{1{\cdot}832} = 216{\cdot}92$; and the molecular distance ratios (topic axial ratios),

$$\chi : \psi : \omega = 6{\cdot}3751 : 8{\cdot}4811 : 4{\cdot}1761.$$

[1] The values given by Abbot (loc. cit.) are 1·8278 (16°), 1·8293 (17°), and 1·8595 (16°). The last of these is perhaps a misprint.

Optics.

Orientation of the Optical Ellipsoid.—Three section-plates ground parallel to the symmetry-plane afforded closely concordant determinations in sodium-light, indicating that one of the directions of extinction lies 12° 40′ behind the normal to $c\{001\}$. This direction is the first median line for all wave-lengths, and as the acute axial angle ac is 73° 53′ this first median line lies 3° 27′ in front of the vertical axis c, as shown in fig. 3. The other extinction-direction in the symmetry-plane lies 12° 40′ above the axis c, and is the second median line for the greater part of the spectrum, from wave-length 0·000664 mm. in the bright red to the violet end. For deeper red radiations, from wave-length 0·000664 to the extreme red of the spectrum, the symmetry-axis b is the second median line. It was

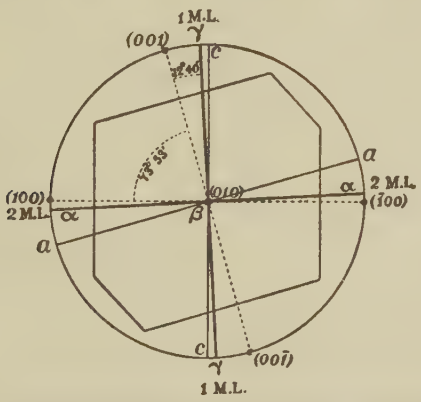

Fig. 3.—Optical orientation of ammonium magnesium chromate.

pointed out by Murmann that the plane of the optic axes is the symmetry-plane $b\{010\}$ for green light, and perpendicular thereto for red light. It will be shown that the exact wave-length for the crossing of the optic axial planes at the ordinary temperature is 0·000664 mm. in the bright red, between lithium- and C-hydrogen-light. The sign of the double refraction is positive.

Refractive Indices.—Six excellent 60°-prisms were ground, each affording two indices. The vibration-direction for the γ-index is the first median line 3° 27′ in front of the vertical axis c, for all wave-lengths; the direction of the symmetry-axis b is that of the a vibrations for red radiations beyond (of deeper red than) wave-length 0·000664 mm., but of β vibrations for all wave-lengths on the yellow side of 0·000664 right through to the blue end; while the direction 12° 40′ above the axis a is

the β-direction for the red side and the a-direction for the yellow-green-blue side. In other words, the two refracted and perpendicularly polarized images of the signal afforded by a 60°-prism cut to transmit light vibrating parallel to the symmetry-axis and to the direction in the symmetry-plane 12° 40′ above the axis a cross one another, and become identical for red light of the wave-length 0·000664 mm. This was directly confirmed with two of the prisms employed, which were so cut (prisms 1 and 2 in the table).

Refractive Indices of Ammonium Magnesium Chromate.

Index.	Vibration direction.	Light.	Prisms 1 & 2.	Prisms 3 & 4.	Prisms 5 & 6.	Mean Index.
a	Symm. axis b.	Li	1·6247–8	...	1·6248–8	1·6248
	12° 40′ from axis a in symmetry-plane.	C	1·6263–4	1·6265–70	...	1·6265
		Na	1·6361–2	1·6364–7	...	1·6363
		Tl	1·6487–8	1·6487–93	...	1·6489
		Cd	1·6568–9	1·6574–5	...	1·6571
β	12° 40′ from a.	Li	1·6249–50	1·6250–2	...	1·6250
		C	1·6266–7	...	1·6268–6	1·6267
	symmetry-axis b.	Na	1·6371–69	...	1·6370–5	1·6371
		Tl	1·6511–3	...	1·6506–4	1·6509
		Cd	1·6602–4	...	1·6601–599	1·6602
γ	8° 27′ in front of vertical axis c.	Li	...	1·6392–4	1·6386–9	1·6390
		C	...	1·6413–8	1·6406–8	1·6411
		Na	...	1·6532–7	1·6527–8	1·6531
		Tl	...	1·6692–5	1·6682–79	1·6687
		Cd	...	1·6802–5	1·6794–5	1·6799

Mean of a, β, and γ for Na-light, 1·6422.

[For other data derived from these constants, see pp. 192–194.]

The intermediate refractive index β corrected to a vacuum (by addition of 0·0004) is expressed by the following formula for any wave-length λ within the range of visibility:

$$\beta = 1{\cdot}6057 + \frac{164\ 219}{\lambda^2} + \frac{32\ 602\ 000\ 000\ 000}{\lambda^4} + \ldots$$

The range of visibility of the spectra produced by prisms of this salt, and of the two other double chromates described in this communication, ceases before the wave-length of F-hydrogen-light is reached, owing to the excessive absorption, by these yellow crystals, of the blue and violet rays. Hence observations for F- and G-light are impossible. In order to record values as near as accuracy permits to the limit of absorption, additional observations were made for light of the green cadmium-line of wave-length 0·0005086 mm.

Refractive Indices at Higher Temperatures.—Determinations were made of the refractive indices at 80° C. The results showed that the refractive

indices at 80° C. were 0·0023 lower than those for the ordinary temperature.

Optic Axial Angle.—Four excellent section-plates were obtained by grinding, perpendicular to the first median line. They all showed the optic interference-figure very clearly in monochromatic light. The figure changes remarkably as the wave-length of the light is varied, owing to the crossed-axial-plane dispersion at the ordinary temperature, the crossing occurring for bright red light between Li and C. For the deep red the optic axes are separated in a plane perpendicular to the symmetry-plane, while for red C-light they are separated in the symmetry-plane, and more and more so for orange, yellow, green, and greenish-blue. The figure becomes invisible before F-hydrogen-light is reached, owing to absorption. Hence, the last measurements were made, as in the case of the refractive indices, for light of the wave-length of the green cadmium line. The measurements of the optic axial angle for light on the red side of the crossing wave-length were made with the section-plate rotated 90°, in its own plane, from the position in which the majority of the measurements (for wave-lengths on the orange side) were made. The exact wave-length for the production of the uniaxial cross and circular rings was determined for both positions, the determinations agreeing most satisfactorily. The values for 2E are given in the first of the following tables. In the second table are given the true optic axial angles, as determined in a similar manner while the section-plate was immersed in a cell of acetylene tetrabromide, the refractive index of which liquid (1·638 for sodium-light) is almost identical with the mean index of the crystals. The usual method of employing a second section-plate perpendicular to the second median line fails in such cases, the optic axes separated at their very large obtuse angle being invisible even in monobromonaphthalene.

Apparent Optic Axial Angle 2E of Am Mg Chromate.

ne of optic axes.	Light.	Section 1.	Section 2.	Section 3.	Section 4.	Mean.
p. symmetry-lane {010}.	Deep red.*	...	...	17° 10′	15° 48′	16° 29′
	Li	9° 47′	11° 57′	8 18	9 20	9 50
allel to sym-etry-plane 010}.	C	14 56	13 27	15 25	14 6	14 29
	Na	45 47	43 53	45 55	44 57	45 8
	Tl	66 33	64 22	66 37	66 31	66 1
	Cd	...	...	...	77 43	77 43

* For this deep red the prism-circle reading 0° 50′ of the spectro-monochromatic illuminator corresponded to the wave-length 0·000684 mm. The figure was still very clear for this wave-length in the case of two of the sections.

The uniaxial cross was produced for the following four readings of the prism-circle in the cases of the four respective sections : 0° 59′, 1° 1′, 1° 0′, and 1° 0′. The mean (1° 0′) of these readings is found, from the wave-length curve, to correspond to wave-length 0·000664 mm. It will be seen from the next table that this result is confirmed by the second series of observations, in which the interference-figure was seen with the axial separation at its true value.

True Optic Axial Angle $2V_a$ of Am Mg Chromate.

Plane of optic axes.	Light.	Section 1.	Section 2.	Section 3.	Section 4.	Mean
Perp. symmetry-plane {010}.	Deep red.*	...	...	11°10′	10°23′	10°47′
	Li	5° 3′	7°20′	5 35	7 1	6 19
Parallel to symmetry-plane {010}.	C	8 7	8 48	9 52	8 49	8 54
	Na	26 49	26 38	26 53	27 13	26 53
	Tl	39 8	38 20	39 10	39 8	38 57
	Cd	...	43 58	44 50	45 4	44 37

* Circle reading 0° 50′ = wave-length 0·000684 mm.

The cross was produced for prism-circle readings 0° 59′, 1° 1′, 1° 0′, and 1° 0′, the mean being 1° 0′, which corresponds to wave-length 0·000664 mm.

Dispersion of the Median Lines.—For all wave-lengths between 0·000664 mm. in the bright red (between Li- and C-light) and the blue end of the spectrum the median lines both lie in the symmetry-plane, and consequently show inclined dispersion. Actual measurements of the latter were made while the section-plates 2 and 3 were immersed in acetylene tetrabromide ; for the nature and amount of the dispersion were accurately shown by the readings of the optic-axial-angle goniometer, during the measurement of the true optic axial angle, the exact orientation of the section plate as regards the original crystal being known. Both series indicated that the first median line lies 1° 10′ nearer to the vertical axis *c* for green cadmium-light than for red C-light.

Effect of Rise of Temperature on the Optic Axial Angle.—When the section-plate perpendicular to the first median line is heated, the uniaxial cross becomes produced for shorter and shorter wave-lengths in turn. Thus at 25° C. the cross is produced for red C-light, and at 50° for a wave-length in the orange corresponding to the prism-circle reading of the spectro-illuminator 1° 20′ (wave-length 0·000636 mm.). That is, for successive temperatures the cross moves along the spectrum towards the yellow. If one illuminates with red C-light, the hyperbolic optic axial

brushes being separated in the symmetry-plane at their angle 2E of $14\frac{1}{2}°$, the effect of warming is to cause the brushes to approach each other, until they coalesce to form the cross (which is surrounded by several concentric circular rings) at 25° C. On moving the prism-circle to 1° 20′, the figure opens out again, but as soon as the temperature has reached 50° it has closed up again to form the cross. At 75° C. the optic axes are still separated 30° for sodium-light and 52° for thallium-light in the symmetry-plane, while for C-light and lithium-light they are respectively separated $32\frac{1}{2}°$ and 37° in the perpendicular plane. All these temperatures are corrected for the conduction of the crystal-holder, which was a special one of wood to reduce conduction to a minimum.

Rubidium Magnesium Chromate, $Rb_2Mg(CrO_4)_2.6H_2O$.

Analysis of 1·1076 grams of clear crystals gave 4·69 per cent. of magnesium (calculated 4·54).

Goniometry.

Crystal system: Monoclinic, holohedral, prismatic. (Class 5.)

Axial ratios and angle: $a : b : c = 0{\cdot}7526 : 1 : 0{\cdot}4953$; $\beta = 104° 49'$.
[Barker's values, $0{\cdot}7558 : 1 : 0{\cdot}4950$; $\beta = 104° 55'$.]

Forms observed: $a\{100\}$, $b\{010\}$, $c\{001\}$, $p\{110\}$, $r'\{\bar{2}01\}$, $o\{111\}$, $o'\{\bar{1}11\}$.

Habit: Short prismatic, or tabular parallel $c\{001\}$.

Cleavage: $r'(\bar{2}01)$, good.

Colour: Yellow, somewhat brighter than the ammonium salt.

The crystals of rubidium magnesium chromate, although apparently beautifully perfect to the eye, are not so easy to obtain with the perfection of planeness of faces which usually characterizes carefully prepared crops of the other two salts. But eventually excellent crystals were obtained, with a dozen of which the measurements were made.

In most crops the *b*-faces were either wanting, or only developed to the extent of narrow strips. The *c*-faces were always large and generally striated parallel to the edge *cq*, affording multiple images. The *p*-faces were also frequently affected by striation parallel to the edge *bp*. One crop of crystals exhibited none other than these two forms {001} and {110}. The *q*-faces were usually very small, and sometimes absent or only present to the extent of two instead of four faces. The *r′*-faces were good when present, but were often missing. The faces of the hemipyramids *o* and *o′* were frequently present, but as a rule gave poor reflections of the signal. The faces of the orthopinakoid $a\{100\}$ are

characteristic of this salt, being well developed in many of the crops. The face in contact with the crystallizing dish was either c, p, or q, never b, and rarely r'.

The crystals were most commonly tabular parallel $c\{001\}$ (fig. 4), and more rarely (in other crops) elongated along the b-axis, with two faces of $p\{110\}$ best developed (fig. 5).

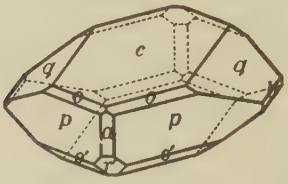

Fig. 4.

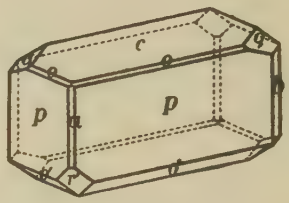

Fig. 5.

Crystals of rubidium magnesium chromate.

Morphological Angles observed on Rubidium Magnesium Chromate.

Angle.	No. of measurements.	Limits.	Mean observed.	Calculated.
$ac = (100):(001)$	1	...	75° 10′	75° 11′
$cr' = (001):(\bar{2}01)$	21	62° 32′ – 62° 41′	62 36	62 24
$r'a = (\bar{2}01):(\bar{1}00)$	1	...	42 21	42 25
$r'c = (\bar{2}01):(00\bar{1})$	23	117 9 – 117 28	117 22	117 36
$ap = (100):(110)$	4	35 59 – 36 5	36 2	36 4
$pb = (110):(010)$	35	53 43 – 54 8	53 56	*
$pp = (110):(1\bar{1}0)$	22	72 3 – 72 14	72 9	72 8
$cq = (001):(011)$	40	25 12 – 25 48	25 36	25 35
$qb = (011):(010)$	38	64 11 – 64 40	64 25	*
$aq = (100):(011)$	1	...	76 47	76 40
$co = (001):(111)$	3	34 5 – 34 21	34 12	34 15
$op = (111):(110)$	1	...	43 49	43 49
$cp = (001):(110)$	40	77 52 – 78 12	78 4	*
$po' = (110):(11\bar{1})$	3	58 12 – 58 13	58 12	58 12
$o'c = (11\bar{1}):(00\bar{1})$	2	43 40 – 43 48	43 44	43 44
$pc = (110):(00\bar{1})$	49	101 47 – 102 7	101 56	101 56
$bo = (010):(111)$	2	70 10 – 70 15	70 12	70 11
$bo' = (010):(\bar{1}11)$	5	65 20 – 65 28	65 25	65 25
$o'o' = (\bar{1}11):(\bar{1}\bar{1}1)$	1	...	49 6	49 10
$qp = (011):(\bar{1}10)$	21	86 3 – 86 24	86 10	86 7
$pq = (\bar{1}10):(01\bar{1})$	24	93 35 – 93 59	93 48	93 53
$qp = (011):(110)$	21	63 43 – 63 55	63 49	63 51
$pq = (110):(01\bar{1})$	20	116 4 – 116 19	116 11	116 9
$r'o' = (\bar{2}01):(\bar{1}11)$	3	34 24 – 34 48	34 34	34 32
$o'p = (\bar{1}11):(110)$	3	91 52 – 92 18	92 3	92 6
$pr' = (110):(20\bar{1})$	31	53 8 – 53 24	53 16	53 22
$r'p = (\bar{2}01):(110)$	29	126 16 – 126 52	126 41	126 38

Volume.

Two series of determinations of the relative density, one made with the dozen crystals which had been used in the goniometrical measurements, yielded the following results for the heaviest crystal in each case:

For 16·5°/4°..... 2·4635..... For 20°/4°..... 2·4628.
„ 17·0°/4°..... 2·4667..... „ „ ..... 2·4660.

The value accepted at 20°/4° is therefore 2·466; from which are calculated the molecular volume, $\frac{M}{d} = \frac{531{\cdot}36}{2{\cdot}466} = 215{\cdot}48$; and the molecular distance ratios (topic axial ratios):

$$\chi : \psi : \omega = 6{\cdot}3403 : 8{\cdot}4246 : 4{\cdot}1727.$$

Optics.

Orientation of the Optical Ellipsoid.—Extinction determinations with three section-plates ground parallel to the symmetry-plane agreed in indicating that one of the extinction-directions lies 27° 1′ for sodium-light forward from the normal to $c\{001\}$. This direction is the third axis of the optical ellipsoid, affording the intermediate refractive index β; and the other extinction-direction in the symmetry-plane is the second

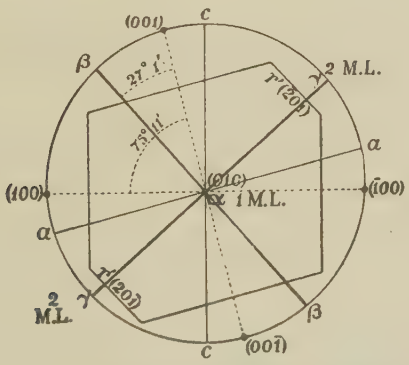

Fig. 6.—Optical orientation of rubidium magnesium chromate.

median line and affords the maximum refractive index γ, the sign of the double refraction being negative. The first median line is the symmetry-axis b, and affords the minimum index α. As the acute angle between the axes a and c is 75° 11′, the third axis of the ellipsoid, the β axis of the indicatrix, lies 41° 50′ in front of the vertical axis c; the second

median line (γ axis) lies 48° 10′ behind the same axis c, and nearly parallel to the normal to $r'\{\bar{2}01\}$, being only 35′ behind the latter (fig. 6).

Refractive Indices.—Of the six 60°-prisms prepared by grinding, four proved satisfactory, whilst the two others being affected by turbidity were discarded.

Refractive Indices of Rubidium Magnesium Chromate.

Index.	Vibration direction.	Light.	Prism 1.	Prism 2.	Prism 3.	Prism 4.	Mean.
α	Parallel symmetry-axis b, 1st M. L.	Li	1·6105	...	1·6106	1·6103	1·6105
		C	1·6119	...	1·6121	1·6114	1·6118
		Na	1·6220	...	1·6217	1·6214	1·6217
		Tl	1·6340	...	1·6347	1·6339	1·6342
		Cd	1·6427	...	1·6429	1·6423	1·6426
β	Nearly par. $r'\{\bar{2}01\}$ in symmetry-plane.	Li	1·6209	1·6208	...	1·6207	1·6208
		C	1·6223	1·6219	...	1·6221	1·6221
		Na	1·6336	1·6326	...	1·6328	1·6330
		Tl	1·6471	1·6466	...	1·6462	1·6466
		Cd	1·6563	1·6560	...	1·6559	1·6561
γ	Nearly perp. $r'\{\bar{2}01\}$ in symmetry-plane, and par. 2nd M.L.	Li	...	1·6307	1·6313	...	1·6310
		C	...	1·6323	1·6329	...	1·6326
		Na	...	1·6430	1·6439	...	1·6435
		Tl	...	1·6575	1·6578	...	1·6577
		Cd	...	1·6671	1·6672	...	1·6672

Mean of α, β, and γ for Na-light, 1·6327.

The intermediate refractive index β corrected to a vacuum (correction +0·0004) is expressed by the following general formula for any wave-length λ within the range of visibility (the blue end of the spectrum being absorbed):

$$\beta = 1{\cdot}5917 + \frac{821\ 732}{\lambda^2} + \frac{21\ 730\ 000\ 000\ 000}{\lambda^4} + \ldots$$

Refractive Indices at Higher Temperatures.—Determinations at 80° C. showed that the refractive indices α, β, and γ diminish respectively by 0·0019, 0·0024, and 0·0025 on raising the prisms from the ordinary to that temperature.

Optic Axial Angle.—Three pairs of section-plates perpendicular to the first and second median lines were obtained by grinding, and the values of $2H_a$ and $2H_o$ measured with them while the plate was immersed in each case in monobromonaphthalene. The apparent angle in air, 2E, is so large as to be unmeasurable, the true angle itself being nearly 90°, in

accordance with the fact that the β refractive index is almost the mean of α and γ. The interference-figures were beautifully clear and sharp, as seen in monobromonaphthalene.

Optic Axial Angle of Rubidium Magnesium Chromate.

Light.	Section.	Observed $2H_a$.	Section.	Observed $2H_o$.	Calculated $2V_a$.	Mean $2V_a$.
Li	1	86° 15′	1 a	89° 17′	88° 26′	88° 27′
	2	86 23	2 a	89 18	88 29	
	3	86 12	3 a	89 15	88 25	
C	1	85 58	1 a	89 37	88 6	88 4
	2	86 2	2 a	89 44	88 5	
	3	85 40	3 a	89 30	88 0	
Na	1	84 35	1 a	91 11	86 34	86 32
	2	84 35	2 a	91 16	86 32	
	3	84 28	3 a	91 11	86 31	
Tl	1	82 48	1 a	93 37	84 26	84 31
	2	82 53	2 a	93 21	84 36	
	3	82 47	3 a	93 23	84 31	
Cd	1	81 47	1 a	95 1	83 12	83 15
	2	81 50	2 a	94 50	83 18	
	3	81 46	3 a	94 51	83 16	

Dispersion of the Median Lines.—Crossed dispersion of the second median line (lying in the symmetry-plane) is exhibited by the crystals of this salt, the first median line being the immovable symmetry-axis *b*. Measurements were made of the positions of the optic axes as seen in acetylene tetrabromide (refractive index for sodium-light 1·638, nearly the same as the mean index 1·633 of the crystals), and from the results the movement of the second median line was calculated. The dispersion of the axes between C- and thallium-light was found to be 3° 16′; and, as 43° 16′ is the mean semi-optic-axial-angle for sodium-light, the dispersion θ of the second median line in the symmetry-plane is afforded by the equation $\cot\theta = \sin 43° 16' \cot 3° 16'$, from which $\theta = 4° 46'$. The direction of movement is such that the second median line is nearer to the axis *a* by 4° 46′ for C-light than for green thallium-light, and by the same amount nearer to the vertical axis *c* for green thallium-light than for red C-light.

This relatively large dispersion of the two principal axes of the optical ellipsoid which lie in the symmetry-plane accounts for the colour shown by a section-plate parallel to the symmetry-plane, when set for extinction in the stauroscope or polarizing microscope.

Caesium Magnesium Chromate, $Cs_2Mg(CrO_4)_2.6H_2O$.

Analysis of 1·0697 grams of crystals gave 4·11 per cent. of magnesium (calculated, 3·86).

Goniometry.

Crystal system : Monoclinic, holohedral, prismatic. (Class 5).

Axial ratios and angle : $a : b : c = 0{\cdot}7431 : 1 : 0{\cdot}4888$; $\beta = 106° 4'$.
[Barker's values, $0{\cdot}7420 : 1 : 0{\cdot}4886$; $\beta = 106° 7'$.]

Forms observed : $a\{100\}$, $b\{010\}$, $c\{001\}$, $p\{110\}$, $q\{011\}$, $r'\{\bar{2}01\}$, $o\{111\}$, $o'\{\bar{1}11\}$.

Habit : Short prismatic, or tabular parallel to $c\{001\}$.

Cleavage : $r'(\bar{2}01)$, good. Colour : Bright yellow.

The dozen individuals, selected from several different crops, used in the goniometry were exceptionally perfect, almost every crystal exhibiting all the forms given in the above list.

The b-faces were small but good. The c-faces were fairly large, but not as a rule so extensive as on the crystals of the rubidium salt. Both these

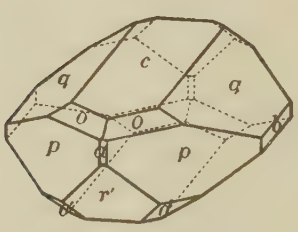

Fig. 7.

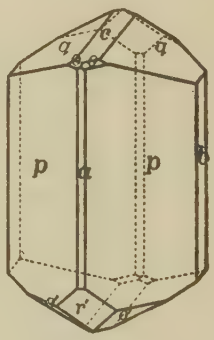

Fig. 8.

Crystals of caesium magnesium chromate.

and the important p-faces were frequently striated parallel to the edges cq and bp respectively, but several of the crystals selected for measurement were free from this defect. The q-faces were uniformly excellent, but sometimes two of four faces were absent. The r'-faces were good and often more largely developed than in the other two salts. The hemipyramids o and o' were nearly always represented by faces affording good

images of the signal. The faces of the orthopinakoid $a\{100\}$ were observed, but were very narrow and the images unsatisfactory, although adequate as evidence of identity. The contact-faces (grown in contact with the crystallizing vessel) were b, a, c, p, and r', and all such c and p-faces were free from striation and afforded perfect images of the signal.

Morphological Angles observed on Caesium Magnesium Chromate.

Angle.	No. of measurements.	Limits.	Mean observed.	Calculated.
$cr' = (001):(\bar{2}01)$	17	63° 13′ — 63° 37′	63° 25′	63° 20′
$r'c = (\bar{2}01):(00\bar{1})$	17	116 23 — 116 50	116 29	116 40
$pb = (110):(010)$	48	54 24 — 54 37	54 30	*
$pp = (110):(1\bar{1}0)$	28	70 48 — 71 6	71 0	71 0
$cq = (001):(011)$	39	24 50 — 25 20	25 9	25 10
$qb = (011):(010)$	38	64 40 — 65 10	64 50	*
$oq = (111):(011)$	3	26 27 — 26 43	26 37	26 39
$co = (001):(111)$	1	...	33 47	33 41
$cp = (001):(110)$	47	76 50 — 77 7	76 59	*
$po' = (110):(11\bar{1})$	21	58 50 — 59 11	58 58	59 4
$o'c = (11\bar{1}):(00\bar{1})$	22	43 50 — 44 9	44 2	43 57
$pc = (110):(00\bar{1})$	47	102 50 — 103 11	103 0	103 1
$bo = (010):(\bar{1}11)$	1	...	70 43	70 41
$bo' = (010):(\bar{1}11)$	17	65 27 — 65 56	65 33	65 34
$o'o' = (\bar{1}11):(\bar{1}\bar{1}1)$	9	48 49 — 49 4	48 58	48 52
$qp = (011):(\bar{1}10)$	35	87 23 — 87 45	87 33	87 32
$pq = (\bar{1}10):(0\bar{1}\bar{1})$	35	92 15 — 92 37	92 27	92 28
$qp = (011):(110)$	30	63 6 — 63 20	63 14	63 12
$pq = (110):(0\bar{1}\bar{1})$	33	116 41 — 116 55	116 47	116 48
$r'o' = (\bar{2}01):(\bar{1}\bar{1}1)$	15	34 33 — 34 59	34 50	34 49
$o'p = (\bar{1}\bar{1}1):(110)$	25	91 37 — 92 5	91 55	91 54
$pr' = (110):(20\bar{1})$	28	53 2 — 53 20	53 9	53 17
$r'p = (20\bar{1}):(110)$	28	126 40 — 126 58	126 51	126 43

Volume.

Three series of determinations of specific gravity, made by the Retgers immersion method, gave:—

For 19·6°/4° ..... 2·7466..... For 20°/4° ..... 2·7465.
„ 18·8°/4° ..... 2·7454..... „ „ ..... 2·7451.
„ 19·6°/4° ..... 2·7466..... „ „ ..... 2·7465.

The accepted value at 20°/4° is consequently 2·747; from which are calculated the molecular volume, $\frac{M}{d} = \frac{625{\cdot}28}{2{\cdot}747} = 227{\cdot}62$; and the molecular distance ratios (topic axial ratios):

$$\chi : \psi : \omega = 6{\cdot}4441 : 8{\cdot}6718 : 4{\cdot}2388.$$

Optics.

Orientation of the Optical Ellipsoid.—Extinction determinations with two section-plates ground parallel to the symmetry-plane $b\{010\}$ indicated that one of the extinction-directions in this plane is situated for sodium-light 25° 26′ behind the normal to $c\{001\}$, and therefore 9° 22′ behind the vertical axis c. This direction is the first median line, and the direction of vibration for the maximum refractive index γ. The other extinction-direction normal to this in the symmetry-plane lies 25° 26′ above the axis a, and is inclined 9° 22′ above the normal to $a\{100\}$ and 80° 38′ in front of the vertical axis c. This principal axis of the optical

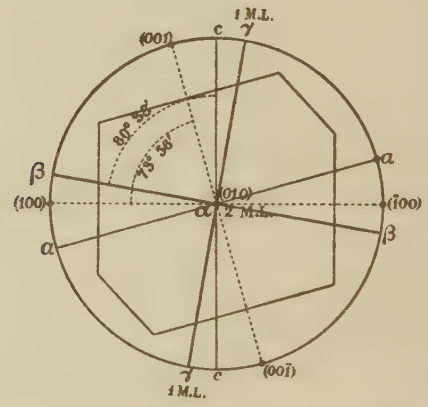

Fig. 9.—Optical orientation of caesium magnesium chromate.

ellipsoid is the third such axis, and the normal to the optic axial plane, and direction of vibration for the intermediate refractive index β. The symmetry-axis b is the second median line and the direction of vibration for the minimum refractive index α. The plane of the optic axes is thus perpendicular to the symmetry-plane. The sign of the double refraction is positive. The above facts will be clear from fig. 9.

Refractive Indices.—Six excellent 60°-prisms were obtained by grinding on the cutting-and-grinding goniometer. Each prism was orientated so as to afford two indices directly, and the results obtained are collected in the following table :

Refractive Indices of Caesium Magnesium Chromate.

Index.	Vibration direction.	Light.	Prisms 1 & 2.	Prisms 3 & 4.	Prisms 5 & 6.	Mean.
a	Parallel symmetry-axis b, 2nd M. L.	Li	...	1·6258–7	1·6261–52	1·6257
		C	...	1·6270–3	1·6275–64	1·6271
		Na	...	1·6367–71	1·6373–65	1·6369
		Tl	...	1·6493–4	1·6495–88	1·6493
		Cd	...	1·6578–9	1·6581–73	1·6578
β	9° 22′ from normal to ortho-pinakoid $a\{100\}$	Li	1·6312–3	...	1·6311–04	1·6310
		C	1·6324–7	...	1·6325–18	1·6324
		Na	1·6429–6	...	1·6426–19	1·6425
		Tl	1·6554–5	...	1·6552–46	1·6552
		Cd	1·6641–2	...	1·6642–33	1·6640
γ	Parallel 1st M.L. 9° 22′ behind vertical axis c.	Li	1·6425–6	1·6420–6	...	1·6424
		C	1·6437–41	1·6435–8	...	1·6438
		Na	1·6549–50	1·6544–5	...	1·6547
		Tl	1·6684–8	1·6682–77	...	1·6683
		Cd	1·6780–3	1·6780–70	...	1·6778

Mean of a, β, and γ for Na-light, 1·6447.

The intermediate refractive index β corrected to a vacuum (correction +0·0004) is expressed for any wave-length λ by the following general formula, with great accuracy for the region from C to Tl, and approximately outside these limits:

$$\beta = 1{\cdot}6051 + \frac{694\ 806}{\lambda^2} + \frac{21\ 436\ 060\ 000\ 000}{\lambda^4} + \ldots$$

Refractive Indices at Higher Temperatures.—Determinations at 80° C. indicated that the refractive indices were reduced by about 0·0026 by raising the prisms from the ordinary to that temperature.

Optic Axial Angle.—Three pairs of section-plates were ground perpendicular to the first and second median lines, and very good values for 2E, $2H_a$, and $2H_o$ were obtained from them, the two latter by immersion in monobromonaphthalene. A fourth very large plate perpendicular to the first median line was also prepared, with natural faces left still visible as evidence of orientation. The following tables express the results:

Apparent Optic Axial Angle 2E of Caesium Magnesium Chromate.

Light.	Section 1.	Section 2.	Section 3.	Section 4.	Mean 2*E*.
Li	131° 3′	131° 7′	131° 0′	131° 0′	131° 3′
C	132 1	131 34	131 35	131 36	131 27
Na	133 19	133 1	132 41	132 39	132 55
Tl	133 39	133 27	133 3	133 17	133 22

The values for the angle in cadmium-light were not sufficiently trustworthy, as the angle was growing so large as to be on the verge of invisibility, and the light feeble owing to absorption.

True Optic Axial Angle of Caesium Magnesium Chromate.

Light.	Section.	Observed $2H_a$.	Section.	Observed $2H_o$.	Calculated $2V_a$.	Mean $2V_a$.
Li	1	67° 10′	1 a	113° 29′	66° 58′	67° 9′
	2	66 59	2 a	113 32	66 50	
	3	66 41	3 a	110 11	67 40	
C	1	67 6	1 a	113 30	66 55	67 7
	2	66 54	2 a	113 34	66 46	
	3	66 40	3 a	110 12	67 39	
Na	1	66 59	1 a	113 35	66 49	67 3
	2	66 48	2 a	113 34	66 42	
	3	66 39	3 a	110 13	67 38	
Tl	1	66 33	1 a	114 1	66 23	66 33
	2	66 17	2 a	113 58	66 12	
	3	66 12	3 a	111 3	67 3	
Cd	1	65 51	1 a	114 28	65 46	65 57
	2	65 52	2 a	114 35	65 44	
	3	65 40	3 a	112 1	66 22	

Dispersion of the Median Lines.—That there was considerable horizontal dispersion of the first median line was clear during the measurements of $2H_a$, the apparent angle in monobromonaphthalene; for the section-plate required to be rotated slightly parallel to the vertically arranged symmetry-plane, in order to adjust the optic axial plane (arranged horizontally) exactly to the horizontal cross-wire for the various colours of the spectrum in succession. One mode of determining the amount of the horizontal dispersion would be to have the adjusting segments of the polariscopical goniometer (the large optic-axial-angle apparatus) graduated, and it is proposed to have silver divided arcs provided on a new instrument for the purpose. The section-plate No. 4—the orientation of which was clearly known from the crystal-faces left on the edges—was arranged so that the plane of the optic axes was vertical, and the planes of the nicols were made vertical and horizontal. The section was then tilted by one of the adjusting segments until one of the optic axes, as seen first in monobromonaphthalene and subsequently in acetylene tetrabromide, was adjusted to the horizontal cross-wire. It was then brought exactly to the vertical wire for red lithium-light, and then for green cadmium-light, by rotation of the goniometer circle, and the readings of the latter for each position taken. The difference of the readings was the apparent disper-

sion of that optic axis in the liquid employed. Monobromonaphthalene has a somewhat higher refractive index (1·6657 for sodium-light), and acetylene tetrabromide a somewhat lower one (1·6380), than the mean crystal index (1·6447), and the mean of the indications may be taken as the true value. It proved to be 3° 14′ in the latter liquid and 3° 10′ in the former one, so that the mean 3° 12′ may be safely taken as the true dispersion of that axis. Similar operations carried out with the other optic axis gave an identical result. The direction is such that the median line will be nearer to the vertical axis c for green cadmium-light than for red lithium-light. The semi-optic-axial-angle for sodium-light being 33° 32′, the dispersion θ of the median line is given by the formula: $\cot\theta = \sin(90° - 33° 32')\cot 3° 12'$, from which θ is found to be 3° 50′. Hence, the first median line is dispersed in the symmetry-plane so that it is nearer to the vertical axis c by 3° 50′ for green cadmium-light than it is for red lithium-light. An identical result was obtained by determining also the position of the axes for sodium-light, and then calculating the difference of position for lithium-light on one side and for cadmium-light on the other. The sum of the two was 3° 50′.

Effect of Rise of Temperature on the Optic Axial Angle.—One of the section-plates perpendicular to the first median line was heated to 70° C. in the heating apparatus of the larger Fuess optic-axial-angle goniometer. The optic axial angle gradually diminished as the temperature rose, until when the latter was constant at 70° (corrected for conduction of the crystal-holder, which was a special one of wood, the correction being even then 10°, the actual reading of the two thermometers in the air-bath being 80°) the apparent angle in air 2E was 130° 3′, whereas at 14° C., under the same conditions before starting the heating, the angle was 132° 27′. There is thus a diminution of 2° 24′ between 14° C. and 70° C., or $2\frac{1}{2}°$ for 56° C. of rise of temperature.

Comparison and Discussion of Results.

Morphology.

Habit.—The rubidium and caesium double chromates containing magnesium exhibit the same general relations of habits as the analogous double sulphates and selenates, namely, on passing from the rubidium to the caesium salt a diminution in the relative development of the basal pinakoid $c\{001\}$ and an increase in the importance of the clinodomal prism $q\{011\}$. The ammonium salt has been found to exhibit almost every variety of habit observed in the series, a property also characteristic of the ammonium salts of the series in general.

Axial Ratios and Axial Angles.—These are compared below:

	a	b	c	β
Ammonium magnesium chromate	0·7517	1	0·4924	106° 7′
Rubidium „ „	0·7526	1	0·4953	104° 49′
Caesium „ „	0·7431	1	0·4888	106° 4′

The axial ratios of the ammonium salt are very close to those for the rubidium salt, and between the latter values and those for the caesium salt. The relations of the axial ratios of the rubidium and caesium salts are similar to those for all the groups (a group containing the same dyad M-metal) of the series, namely, the ratios diminish on passing from the rubidium to the caesium salt.

The axial angles of the ammonium and caesium salts are very nearly identical, a fact which has been shown to be true in all the groups of double sulphates and selenates yet fully investigated. The axial angle increases by 75′ on replacing rubidium by caesium, and this fact also is in complete agreement with the results for the double sulphates and selenates, an increase of slightly more than a degree being general on replacement of rubidium by caesium.

The Crystal Angles.—These are compared in the accompanying table, from an inspection of which the following conclusions may be drawn:

The differences between the angles of the rubidium and caesium salts are of the same sign and order as those between the rubidium and caesium salts of all the groups of double sulphates and double selenates known to belong to the series $R'_2M''[(S,Se)O_4]_2.6H_2O$. Thus, for instance, if one compares the last column of the table, which shows these differences for the magnesium group of double chromates, with the column of differences given in the tables of angles of the rubidium and caesium salts of the manganese and cadmium groups of double sulphates[1]—groups which are especially similar, as no potassium salts have yet been obtained belonging to them—it will be found that the signs indicating the direction of change (an increase of angle being + and a diminution −) are the same, and that the actual amounts of change are very similar. The same is true if any of the other six tables given in that memoir for the other groups of double sulphates are compared with the table now given; and also if the tables for the magnesium and zinc groups of double selenates[2] are examined.

Hence there can be no doubt that if the potassium salt of this magnesium chromate group could be prepared, the three salts of the magnesium group

[1] A. E. H. Tutton, loc. cit., 1893, pp. 379 and 413.
[2] A. E. H. Tutton, loc. cit., 1905, p. 1167.

Comparison of the Calculated Morphological Angles.

Angle.	Am Mg Chromate.	Rb Mg Chromate.	Cs Mg Chromate.	Diff. between Rb and Cs salts.
$ac = (100):(001)$	73° 53′	75° 11′	73° 56′	−75′
$as = (100):(101)$	45 51	46 40	45 47	−53
$sc = (101):(001)$	28 2	28 31	28 9	−22
$cr' = (001):(\bar{2}01)$	63 11	62 24	63 20	+56
$cs' = (001):(\bar{1}01)$	37 33	37 21	37 43	+22
$s'r' = (\bar{1}01):(\bar{2}01)$	25 38	25 3	25 37	+34
$r'a = (\bar{2}01):(\bar{1}00)$	42 56	42 25	42 44	+19
$r'c = (\bar{2}01):(00\bar{1})$	116 49	117 36	116 40	−56
$ap = (100):(110)$	35 50	36 4	35 30	−34
$pp' = (110):(120)$	19 28	19 28	19 28	0
$p'b = (120):(010)$	34 42	34 28	35 2	+34
$pp''' = (110):(130)$	29 23	29 20	29 27	+ 7
$p'''b = (130):(010)$	24 47	24 36	25 3	+27
$pb = (110):(010)$	54 10	53 56	54 30	+34
$pp = (110):(1\bar{1}0)$	71 40	72 8	71 0	−68
$cq = (001):(011)$	25 19	25 35	25 10	−25
$qb = (011):(010)$	64 41	64 25	64 50	+25
$ao = (100):(111)$	48 57	49 47	48 51	−56
$oq = (111):(011)$	26 31	26 53	26 39	−14
$aq = (100):(011)$	75 28	76 40	75 30	−70
$qo' = (011):(\bar{1}11)$	33 57	33 46	34 10	+24
$o'a = (\bar{1}11):(\bar{1}00)$	70 35	69 34	70 20	+46
$co = (001):(111)$	33 40	34 15	33 41	−34
$op = (111):(110)$	43 20	43 49	43 18	−31
$cp = (001):(110)$	77 0	78 4	76 59	−65
$po' = (110):(11\bar{1})$	59 6	58 12	59 4	+52
$o'c = (11\bar{1}):(00\bar{1})$	43 54	43 44	43 57	+13
$pc = (110):(00\bar{1})$	103 0	101 56	103 1	+65
$bn = (010):(121)$	54 45	54 13	54 59	+46
$no = (121):(111)$	15 47	15 58	15 42	−16
$bo = (010):(111)$	70 32	70 11	70 41	+30
$os = (111):(101)$	19 28	19 49	19 19	−30
$bo' = (010):(\bar{1}11)$	65 22	65 25	65 34	+ 9
$o's' = (\bar{1}11):(\bar{1}01)$	24 38	24 35	24 26	− 9
$o'o' = (\bar{1}11):(\bar{1}\bar{1}1)$	49 15	49 10	48 52	−18
$sq = (101):(011)$	37 4	37 35	37 3	−32
$qp = (011):(\bar{1}10)$	87 19	86 7	87 32	+85
$ps = (\bar{1}10):(\bar{1}0\bar{1})$	55 37	56 18	55 25	−53
$pq = (\bar{1}10):(0\bar{1}\bar{1})$	92 41	93 53	92 28	−85
$s'q = (\bar{1}01):(011)$	44 13	44 11	44 17	+ 6
$qn = (011):(121)$	26 3	26 26	26 9	−17
$np = (121):(110)$	36 58	37 25	37 3	−22
$qp = (011):(110)$	63 1	63 51	63 12	−39
$ps' = (110):(10\bar{1})$	72 46	71 58	72 31	+33
$pq = (110):(0\bar{1}\bar{1})$	116 59	116 9	116 48	+39
$r'o' = (\bar{2}01):(\bar{1}11)$	34 57	34 32	34 49	+17
$o'p = (\bar{1}11):(110)$	91 28	92 6	91 54	−12
$pr' = (110):(20\bar{1})$	53 35	53 22	53 17	− 5
$r'p = (\bar{2}01):(110)$	126 25	126 38	126 43	+ 5

of double chromates containing respectively potassium, rubidium, and caesium as the R-metal would form a eutropic series, exhibiting the progression according to the atomic weight of the alkali metal, which has been shown to be a general property in all the groups of this isomorphous series.

As regards the angles of the ammonium salt, they are so similar to those of the other two salts that there can be no hesitation whatever in allocating ammonium magnesium chromate to the monoclinic isomorphous series in question; and in the great majority of cases the angles are very close indeed to those of caesium magnesium chromate. A careful analysis shows that out of 48 angles compared, 36 are nearer (usually very near) to the corresponding angle of the caesium salt, and only 12 are nearer to that of the rubidium salt. In 27 cases the value for the ammonium salt lies between the values for the rubidium and caesium salts, in 16 cases it lies beyond the caesium salt, and in 5 cases below the rubidium salt.

Thus the ammonium salt, although belonging to the isomorphous series, shows no progression entitling it to inclusion in the eutropic series to which the rubidium and caesium salts belong.

It is interesting to see what is the effect on the angular magnitudes of the replacement of sulphur by selenium and by chromium. A comparison has been made of the respective analogous angles of rubidium magnesium sulphate, selenate, and chromate, and also of those of caesium magnesium sulphate, selenate, and chromate. No progression according to the atomic weights of sulphur, chromium, and selenium (respectively 31·82, 51·6, and 78·6) is exhibited. The vast majority of the angles of the chromate lie beyond those of the selenate, a very few indeed lying between those of the sulphate and selenate. Thus the fact that chromium does not belong to the eutropic series containing sulphur and selenium is clearly brought out. For chromium belongs to the even series of Mendeléeff's sixth group, while sulphur and selenium belong to the odd series.

Volume.

The volume constants are compared in the next table:

Volume Constants of Magnesium Chromate Group.

Salt.	Density at 20°/4°.	Molecular volume.	Molecular distance ratios.		
			χ	ψ	ω
Am Mg chromate	1·832	216·92	6·3751	8·4811	4·1761
Rb Mg ,,	2·466	215·48	6·3403	8·4246	4·1727
Cs Mg ,,	2·747	227·62	6·4441	8·6718	4·2388

The molecular volume and molecular distance ratios of the ammonium salt are thus nearly identical with those of the rubidium salt, and lie between those for the rubidium and caesium salts. This is a similar result to that afforded by a comparison of the ammonium salts of the sulphate and selenate groups investigated. The increase of molecular volume brought about by the replacement of rubidium by caesium is 12·14 units, which is very close to the average increase, 12·7 units, observed in the sulphate and selenate groups; and the extension of the structure, indicated by the increase of the molecular distances, is also of the same order as that observed in these groups.

Optics.

Orientation of the Optical Ellipsoid.—It has been shown to be general throughout the whole isomorphous series, that the optical

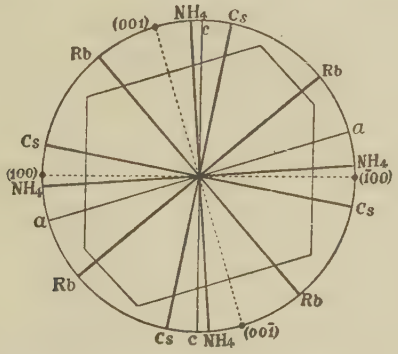

FIG. 10.—Optical orientation of the double chromates.

ellipsoid rotates about the symmetry-axis *b* when the alkali base is changed. This rotation has, further, been shown to follow the order of the atomic weights of the metals in the cases of potassium, rubidium, and caesium salts. The order has always been [1]: ammonium salt, potassium salt, rubidium salt, caesium salt. The *a* axis of the ellipsoid of the ammonium salt has always been close to the vertical axis *c*, and that of the potassium salt has followed closely at a slightly greater angle in front of the vertical axis; then in front of this again come the rubidium and caesium *a* axes in succession; and the result in all cases has been that the rubidium *a* axis is about midway between the

[1] A. E. H. Tutton, loc. cit., 1905, p. 1172.

ammonium a axis and the caesium a axis. Throughout the whole series of the double sulphates and selenates the optic axes lie in the symmetry-plane. This is precisely so in the case of the magnesium chromate group under discussion, as regards the extinction-directions in the symmetry-plane, as will be clear both from fig. 10 and from the following table, which gives the angular distance of one of the axes of the ellipsoid from the vertical axis c.

Inclination of Axis of Indicatrix to (in front of) Vertical Axis c.

Am Mg chromate	...	...	...	...	3°	27′
Rb Mg	,,	...	...	...	...	41	50
Cs Mg	,,	...	...	...	...	80	38

The chromates show their individuality, however, by the fact that the axis in question is not the a axis, but the β axis in the case of the rubidium and caesium salts, and the γ axis in the case of the ammonium salt.

Refractive Indices.—The principal and mean indices, the double refraction, etc., for sodium-light are compared in the following table (for other wave-lengths see the detailed description of each salt):

	Am Mg. chromate.	Rb Mg chromate.	Cs Mg chromate.
a (Na-light) ...	1·6363	1·6217	1·6369
β ,, ...	1·6371	1·6330	1·6425
γ ,, ...	1·6531	1·6435	1·6547
$\frac{1}{3}(a+\beta+\gamma)$,, ...	1·6422	1·6327	1·6447
$\gamma-a$,, ...	0·0168	0·0218	0·0178
Sign of double refraction ...	positive	negative	positive
2V (Na-light) ...	26° 53′	86° 32′	67° 3′
Axes of the optical indicatrix $a:\beta:\gamma$ (Na) ...	0·9995 : 1 : 1·0098	0·9931 : 1 : 1·0064	0·9966 : 1 : 1·0074

The refractive power of the crystals of this group is very high, much higher even than that of thallium zinc sulphate, of which the mean index is 1·6064, the maximum hitherto observed in the series. This will be clearly apparent from the following comparison of the mean refractive indices (for sodium-light) of the nine salts of the three groups containing magnesium. And it is again obvious that the double chromates, although belonging to the same isomorphous series, are not in the same eutropic series as the double sulphates and selenates.

Mean Refractive Indices of the Salts of the three Magnesium Groups.

	Chromate.	Sulphate.	Selenate.
Am Mg	... 1·6422	... 1·4744	... 1·5111
Rb Mg	... 1·6327	... 1·4713	... 1·5059
Cs Mg	... 1·6447	... 1·4877	... 1·5198

The refractive indices of rubidium magnesium and caesium magnesium chromates show the usual progression with atomic weight, which has been shown to be general throughout the series. The crystals of ammonium magnesium chromate prove to refract light to almost the same extent as the caesium salt, the mean refractive index being slightly lower than that of the latter but much higher than the mean index of the rubidium salt. The α and β indices of the ammonium salt are almost identical for the red end of the spectrum, and indeed they are actually identical for bright red light of wave-length 0·000664 mm. (between lithium- and C-light), the directions of vibration for the α and β indices interchanging on the two sides of this wave-length.

The double refraction is also high as compared with that of the double sulphates and selenates. It shows a diminution on passing from the rubidium to the caesium salt, in accordance with the rule found for the whole series: namely, that in any eutropic series of which potassium, rubidium, and caesium are the interchangeable metals the double refraction diminishes with rise of atomic weight of the interchanged metal. The double refraction of the ammonium salt is slightly lower still than that of the caesium salt, whereas in the sulphates and selenates it is always intermediate between the values for the rubidium and caesium salts.

Dispersion.—The dispersion is also much higher than in the double sulphate and selenate groups. The maximum dispersion in the magnesium sulphate group between lithium- and G-light is 0·0132 (in the case of ammonium magnesium sulphate), and in the magnesium selenate group 0·0173 (for ammonium magnesium selenate). The following much higher figures are found for the magnesium chromate group, and they refer to a less extended part of the spectrum, from the red lithium to the green cadmium-line only, as absorption occurs beyond this, the crystals being deeply coloured yellow.

Dispersion of Double Chromates between Li- and Cd-light.

	α	β	γ
Am Mg chromate	... 0·0323	... 0·0352	... 0·0409
Rb Mg „	... 0·0321	... 0·0353	... 0·0362
Cs Mg „	... 0·0321	... 0·0330	... 0·0354

Molecular Refraction, etc.—The following values are calculated from the data recorded in previous pages:

Molecular Optical Constants.

		α	β	γ	Mean $\frac{1}{3}(\alpha+\beta+\gamma)$
Specific refraction, $\frac{n^2-1}{(n^2+2)d}$ for ray *C*.	Am Mg chromate	0·1933	0·1934	0·1969	
	Rb Mg ,,	0·1409	0·1428	0·1448	
	Cs Mg ,,	0·1290	0·1299	0·1372	
Molecular refraction, $\frac{n^2-1}{n^2+2}\cdot\frac{M}{d}$ (Lorenz) for ray *C*.	Am Mg chromate	76·84	76·86	78·26	77·32
	Rb Mg ,,	74·88	75·90	76·92	75·90
	Cs Mg ,,	80·69	81·23	85·80	82·57
Molecular refraction, $\frac{n-1}{d}M$ (Gladstone & Dale) for ray *C*.	Am Mg chromate	135·90	135·94	139·07	136·97
	Rb Mg ,,	131·83	134·05	136·31	134·06
	Cs Mg ,,	142·74	143·95	146·54	144·41

The molecular refraction of the ammonium salt is thus seen to be very slightly higher than that of the rubidium salt, and the increase of atomic weight when rubidium is replaced by caesium is accompanied by a considerable increase of molecular refraction. Both facts are analogous to those previously found for the double sulphate and selenate groups containing either magnesium or any other of the eight dyad-acting metals forming the series.

These conclusions are independent of the temperature; for it was definitely determined that the refractive indices of the crystals diminished on raising the temperature, so that the effect of rise of temperature acts in the same direction, that of lowering, on both the refraction and the density.

General Conclusions.

Three main conclusions are to be derived from this investigation, concerning respectively (1) the relations of the rubidium and caesium magnesium chromates, (2) the position of ammonium magnesium chromate, and (3) the relations of these double chromates to the analogous double sulphates and selenates previously studied.

(1) Rubidium magnesium chromate and caesium magnesium chromate have been found to exhibit crystallographic characters precisely similar in

their mutual relationships to those of the rubidium and caesium salts of every group of double sulphates and double selenates already studied. The parallelism extends to every property investigated. There can be no doubt that if the potassium salt of the group were capable of formation and could be prepared, the three double chromates containing potassium, rubidium, and caesium would exhibit the progression of a eutropic series, in accordance with the atomic weight of the alkali metal, the revelation of which has been one of the main results of the previous investigations by one of us. Indeed, it would be quite simple to predict the crystallographic constants of the missing potassium salt. We have here only another evidence of the eutropic progression, for the caesium salt is highly stable, the rubidium salt exhibits a tendency to efflorescence and to become opaque in course of time, while the potassium salt will not form at all. This progression as regards facility of formation of potassium, rubidium, and caesium salts was also well shown in the case of the copper group of double sulphates, in which the potassium salt was obtained with difficulty, in very small crystals which only very occasionally were clear and transparent; the rubidium salt was more readily obtained in crystals free from turbidity; while those of caesium copper sulphate were characteristically clear and limpid.

(2) The position of the ammonium salt in the magnesium group of double chromates has been shown to be similar to that found in general for the ammonium salt of any group of double sulphates or double selenates of the series. As regards morphology the crystal angles have been shown to be in a large majority of cases very nearly identical with those of caesium magnesium chromate, and in general so similar to the angles of both the rubidium and caesium salts that there can be no hesitation in allocating ammonium magnesium chromate to the isomorphous series $R'_2M''[(S,Se,Cr)O_4]_2.6H_2O$. No rule of progression with atomic or molecular weight applies, however, so that the ammonium salt stands outside the eutropic set of which the only two members yet produced are the rubidium and caesium magnesium chromates. As regards structure, the molecular volume and distance ratios of the ammonium salt have been shown to be nearly identical with those of the rubidium salt, the slight difference leaning towards the caesium values. A similar remark applies to the molecular refraction, while the actual values of the refractive indices, of the mean refractive index, and of the amount of double refraction, are very near to those of the caesium salt. The similarity of the structural constants of the ammonium and rubidium salts of this group confirm in a particularly valuable manner, owing to the independent nature of chromic

acid as distinguished from sulphuric and selenic acids, the conclusion derived from former work, that the replacement of potassium by ammonium in any group of this isomorphous series is accompanied by practically no more extension of the crystal structure than when rubidium is introduced for potassium, the ten atoms of the two ammonium groups NH_4 apparently going into the same space as the two atoms of rubidium.

(3) With respect to the effect of replacing the negative element sulphur or selenium by chromium, the evidence is clear that these three elements do not give rise to a eutropic series including all three, sulphur and selenium alone belonging to a eutropic series which might also conceivably include tellurium. Chromium, like ammonium in the case of the bases, in the form of chromic acid gives rise to double chromates which belong truly to this isomorphous series, which may thus be written legitimately as $R'_2M''[(S,Se,Cr)O_4]_2.6H_2O$; but these double chromates show no progression according to the atomic weight of chromium, that is the order S, Cr, Se (31·82, 51·6, and 78·6) is not followed in these salts. The refractive indices of the double chromates, and also their double refraction and dispersion, are much higher than those of the double sulphates and selenates, and even their molecular refractions are outstandingly high, although their structural constants, the molecular volume and distance ratios, lie mainly between the values for the corresponding sulphates and selenates, and entirely so as regards the volume. In many other details of the optical properties the double chromates have also shown their individuality. The interfacial angles lie mostly beyond those of the double selenates.

The final result of this investigation has thus been to afford a further and independent proof of the relations between the ammonium, potassium, rubidium, and caesium salts of any one and the same group (containing the same M-metal) of this isomorphous series; and to confirm in every detail the conclusions derived from those former investigations, that the potassium, rubidium, and caesium salts of any such group form a eutropic set or inner series, rigidly following a law of progression of the crystallographic properties with the atomic weight of the alkali metal, while the ammonium salt of the group belongs truly to the isomorphous series but not to the more exclusive eutropic series within it.

On Rathite and its variety, Wiltshireite.

By Professor W. J. Lewis, M.A., F.R.S.

[Read November 15, 1910, and March 21, 1911.]

Introduction.

THE main portion of this memoir as far as it relates to wiltshireite was in the Editor's hands in January, 1911; but before it was sent by him to press I learnt that Mr. R. H. Solly had, at the Anniversary Meeting of the Mineralogical Society in 1903, described an unnamed crystal, which, from the statement made to the Society on March 21, 1911, and published in the 'Mineralogical Magazine' (1911, vol. xvi, p. 121), is undoubtedly the same substance as that named by me in August, 1910, wiltshireite.[1] In the statement of March, 1911, Mr. Solly pointed out the striking relation of the crystals of wiltshireite to those of rathite; and suggested that the latter is oblique and not orthorhombic, as described in this Magazine (1901, vol. xiii, pp. 77–85). I consequently postponed publication until I could examine such crystals of rathite as were available. With this object I appealed to Professor Baumhauer for the loan of his standard crystal of rathite, described in Groth's 'Zeitschrift' (1896, vol. xxvi, pp. 593–602); and he with great courtesy at once sent it to me. I beg leave here to thank him for his kindness. The account of my examination of this crystal is given under viii; but I may here state that the terminal faces, though poor and probably compound, are easily referable to similarly placed faces of wiltshireite; and that the crystal is to be regarded as a complex twin with (100) and (101) of wiltshireite as twin-faces. My examination of the several rathite crystals confirms Mr. Solly's inference that rathite is oblique. For convenience, the name wiltshireite is retained in this paper to distinguish the comparatively simple crystals such as that described by me in August, 1910, from the more complex twins to which Professor Baumhauer's crystal is referred. I may state that I found no true cleavage; but I got a good parting parallel to (100), which I believe to be due to twin-lamellation parallel to this face.

[1] Phil. Mag., 1910, ser. 6, vol. xx, pp. 474–475.

Wiltshireite.

System, Oblique: $a : b : c = 1{\cdot}5869 : 1 : 1{\cdot}0698$; $\beta = 79° 16'$.

Forms observed; those marked with a ? being doubtful. A large number of them are indicated on the stereogram, fig. 1.

A (100), C (001), (501) ?, (401) ?, h (301), t (201), ζ (302), d (101), ϕ (102), w ($\bar{1}02$), u (203), z ($\bar{1}01$), χ (302), y ($\bar{2}01$), k^* (522) ?, δ (211), e (322), g (111), τ (344), σ (122), n (011), o ($\bar{1}22$), p ($\bar{1}11$), x (322), λ ($\bar{2}11$), κ ($\bar{5}22$), i ($\bar{3}11$), μ ($31\bar{2}$), η ($52\bar{4}$), π ($21\bar{2}$), ϵ ($32\bar{4}$), Δ ($11\bar{2}$), γ (012), Σ (112), θ (510), ρ (920), (410), l (310), ψ (520), r (210), (740), s (320), (540), (650), m (110), ω (340), f (120), a (250).

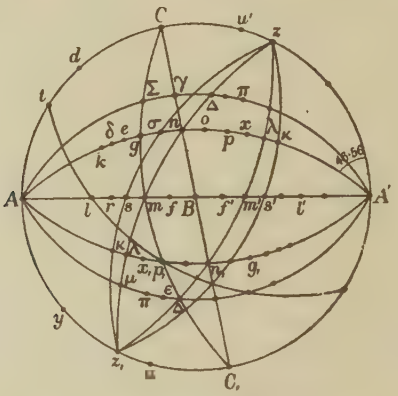

Fig. 1. Stereogram of Wiltshireite.

The crystals which I have examined are described below.

Crystal i.—The first, on which the note in the 'Philosophical Magazine' of September, 1910, is based, is rich in faces; but most of the end ones have two or more separate portions which reflect the light simultaneously, or very nearly so. The crystal is about 5 mm. long by 1·5 mm. across, and may to some extent be compared to a pile of minute needles with ends loaded with facets. Several faces give two images, coming probably from separated portions of a face, i. e. from the facets on different rods. The separation of the images is specially noticeable in measuring the zones $[Bpz]$ and $[BnC]$; when the images from each face are separated by some 10′ to 14′. When the zone $[Agp] = [01\bar{1}]$ was perceived, it and the homologous zone were both measured; and, as shown by the table of angles, they give trustworthy readings. To eliminate as far as possible the uncertainty arising from faces giving two images, a number of *cross-zones*, e. g. such as $[110, 10\bar{1}]$, were measured;

and the angle $pAC = 46° 56'$ was determined from nine triangles, the poles forming them being those of the faces which had given the best readings. This angle is nearly the complement of the angle (100) : (101) $= 43° 5\frac{1}{2}'$ given by Mr. Solly in his memoir on rathite (this Magazine, vol. xiii, p. 79).

The presence of minute facets which lie in zones [100, 012] was perceived at an early period; and, as far as possible, their position in the cross-zones was determined. They are, as a rule, much smaller than facets of the series (*hll*) and give very faint images. They were of service in settling the character of crystal ii.

The prism-faces are uneven and are, so to speak, built up of portions of several rods. They are free from the oblique striae characteristic of rathite crystals; but give poor direct readings. They are somewhat tarnished, and have a brown tint; and the lustre, though metallic, is much as if the crystals had been rubbed with oil. The end facets are very white and bright.

The crystal lies in a cavity in dolomite at the bottom of which is a crystal of sartorite, proved by measurement of its prism-zone. Only that end which I have selected as the positive end of OZ is sufficiently exposed for measurement; and the face y (20$\bar{1}$) in its true place was only observed after my note had been sent to the 'Philosophical Magazine'. The face giving the angle 40° 11′, and for which the symbol (302) was suggested in that note, lies between (100) and (001). The evidence supplied by the set of crystals of the accuracy and constancy of the angles of wiltshireite, and also in crystal iv of twinning with (100) as twin-face, makes it fairly certain that the face in question is y in twin-orientation. At the time I had no data on which an explanation of the discrepancy could be based. Later on, when the presence of y and twinning with (100) as twin-face had been established, such an explanation became obvious. It may be here pointed out that an angle of 40° 14′ to 40° 30′ measured in a pinakoid-zone from the conspicuous pinakoid is common to all the lead sulpharsenites except jordanite. It is further probable, as pointed out by Mr. Solly, that the face to which the symbol (522) has been assigned is the face (31$\bar{1}$) in twin-orientation on the same lamella as y; for (100) : (31$\bar{1}$) $= 38° 4'$. The divergence of the observed angle from the computed one is then 3′ instead of 34′. The face (31$\bar{1}$) has only been observed in its true place on crystal iii.

Crystal ii.—This crystal is smaller than i, and is implanted in an apparently regular orientation on a plate of one of the lead sulpharsenites which I am inclined to think is rathite; but the angles on it which I

have measured do not enable me to determine this with certainty. Some of its faces reflect the light simultaneously with faces of wiltshireite, and the (100) of the latter is parallel to the large face of the underlying plate. The end facets on ii which are best exposed are those which meet OZ at its negative end. The lustre is like that of i.

Crystal iii.—This was broken in an attempt to clear some of the dolomite out of the way: its broken end is nearly spherical and gives very fair readings. The fracture is conchoidal, and seems inconsistent with a cleavage. Such fracture surfaces parallel to (100) as have been observed at broken places on this and other crystals seem to be due to twin-lamellation parallel to (100). The small top shows in a striking way one of the peculiarities of the crystals; for the facets are not in all directions bounded by definite edges, but are like those seen on round grains of olivine extracted from the Pallas meteoric iron. The measured fragment has a minute crystal of sartorite attached to it; and there is reason to think that the zones [010] of the two crystals coincide, but the faces (100) of the two are at 12° 57′ to one another.

Crystal iv.—This is a very minute isolated fragment differing from the preceding crystals in the freshness of its colour and lustre; and in this respect it resembles Professor Baumhauer's crystal of rathite. It shows fine striation parallel to (100) on the faces (101), (102) and (122); striae due probably to twin-lamellae with (100) as twin-face. They cause an unusual disturbance of the angles in the zones [100, 111]. For in one of them the face $\sigma(122)$ gives two images; the better one making an angle of 69° 45′ with (100), the poorer one the correct angle 70° 2′ given in the table. In the second zone $g_1(1\bar{1}1)$ is ill-developed, and gives a blurred bar of light and not a definite image; the angle Ag_1 being 58° 39′. In the zone $[gdg_1]$ the angle gd is 38° 15′, g_1d 39° 29′, both very appreciably different from the computed angle 38° 50′. Two of the {120} faces show also oblique striae such as are characteristic of rathite; so that this crystal may perhaps be better regarded as a good crystal of the latter rather than one of the simple form.

Crystal v.—This is an isolated group of two or three slender rods of wiltshireite deposited on a relatively large crystal of rathite in nearly parallel orientation with a face (100) in common. The faces of wiltshireite are fresher and brighter than those of rathite; and the group may be compared with one of redruthite in which a number of small crystals are deposited on a tabular altered crystal of earlier formation. The end faces of wiltshireite are $(20\bar{1})$, (111), and $\sigma(122)$ or $p(\bar{1}11)$.

ndependently of probable twinning with (100) as twin-face, certainty to the last face being σ or p is unattainable; for the (100) faces of ne group give three images, the extreme ones being nearly $1\frac{1}{4}°$ apart. he prism-faces l, r, s, m, f were identified in a zone common to wilt-ireite and rathite. On the rathite crystal two zones [010] and [01$\bar{1}$] re perceived, the faces in the latter forming fairly long ridges with -entrant angles. The angles measured in these two zones were poor, ut they seem to prove the presence of (302) in one zone, and of (011) simple and twin orientation in the other. Further, the angle between e prism-zone and [01$\bar{1}$] was found to be 43° 30′.

Other crystals having the distinctive colour and oily appearance of e first three specimens have been observed implanted on, or mixed up ith, other lead sulpharsenites, especially sartorite; but they have oken ends, which leave their character doubtful, for the prism-zone is o uncertain to be relied upon.

Rathite.

From the table of angles and the description of the crystals vi–viii will be seen that they can be regarded as twins of the simple crystal wiltshireite; and consequently rathite is oblique and not prismatic.

Crystal vi.—This is a tarnished characteristic crystal of rathite, ough it shows no oblique striae on the prism-faces. In the zone 01$\bar{1}$] fairly large faces e, g, σ, n, o, and p occur; in [011] two slightly eveloped faces are inclined to (100) at 59° 48′ and 70° 28′, so that it is oubtful whether they are g and σ, or x and p in twin-orientation. urther in the prism-zone an image at 90° 50′ to (100) was observed, hich is possibly due to numerous ridges combining to simulate (010).

Crystal vii.—Fig. 2 is a fairly accurate sketch of the best rathite rystal (No. 2835) in the Cambridge collection. It is about 8 mm. long y 2 mm. wide and 2 thick; and is still attached to a small piece of olomite which prevents complete measurement, and the left side in the ketch is that best exposed. Owing to the crystal's development the egative end of OZ is uppermost. The prism-faces f, r, s, &c. are, save on he central portion marked by $\underline{A}$ and $\underline{y}$, finely striated in an oblique irection which seems to coincide with the trace of a plane parallel to 101). Across the portions marked A and A_0 of the large pinakoid here are less numerous, but very strongly developed, lines perpendicular o the prism-edges. On the part A these lines are interrupted on the ight by three or four fine lines parallel to the prism-edges; but a few f them reappear near the right-hand edge. On A_0 they seem to extend

from side to side. These striae on pinakoid and prisms accord with the view that they are due to twin-lamination with (101) for twin-face. Mr. Solly (this Magazine, vol. xiii, pp. 80 and 83) gives the twin-face as (074), which by the table given further on is strictly (17·0·16) of wiltshireite, though his approximate determination fits well enough with (101). On the portion marked $\underline{A}$ there are no such transverse lamellar markings, but only very fine lines parallel to the prism-edges. At the place marked by a stroke-and-dot line there is a small re-entrant angle. Measurement of the zone $[Ay]$ gave for Ay and for $A\underline{y}$ the same angle 40° 25′; for $A\underline{A}$ 1° 59′, and for $\underline{yy}$ 78° 54′. Subtracting the last from 2 × 40° 25′, we have 1° 56′ for the re-entrant angle. Now a possible face ($\bar{1}04$) on wiltshireite is inclined to (100) at an angle of 88° 58′; and twinning about the normal to this face gives 2° 4′ as the re-entrant angle between the twinned pinakoids 100 and ($\bar{1}00$). The twinned portion indicated by $\underline{A}$ and $\underline{y}$ does not extend the whole thickness; and the prism-faces near $\underline{A}$ are free from the oblique striae which are seen at the two ends of the crystal. There is a fine crack across the crystal, where the flaw is marked on A_0, and this portion of the face is inclined at an angle of about 14′ to that marked A.

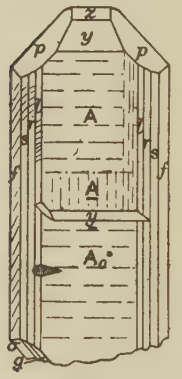

Fig. 2.—Rathite (Crystal vii).

The faces p were covered with a layer of dull earthy galena or soot-like matter, and the other hemipyramids were likewise very dull. Glass-plates were first gummed to the two large p faces, and approximate readings obtained from them. Afterwards the hemipyramids were all gently rubbed and fresh readings taken. The angles found afford satisfactory evidence that the faces are the same as p, o, σ, g, and e of wiltshireite.

Crystal viii.—Fig. 3, the cliché of which has been kindly supplied by Professor von Groth, is the idealized plan given by Professor Baumhauer of his standard crystal of rathite described in Groth's 'Zeitschrift', vol. xxvi, p. 593 et seq. The pinakoid labelled (001) is my (100); and both faces are throughout their length deeply grooved perpendicular to the prism-edges in a way characteristic of twin-lamellae. One of its faces gives two images—one yellowish, one white—inclined to one another at an angle of 11′; and my impression is that the yellow image (denoted by A) is the more trustworthy, and the readings in the zones [100, 001] and [100, 111] are taken from it. The parallel face A, gives a number of close images separated by a few minutes, and a mean

value has been taken. Again, with one exception, the pinakoids at the two ends (Baumhauer's brachydomes) give more than one image. Of his form {045} there are three faces, for which he adopts the angle (001) : (045) = 40° 14.5′; whilst he points out the differences which exist in the measured values. Reading from the yellow image *A*, I get at one end *Ay* = 40° 1′ (a good angle); and at the other end 40° 16′ and 40° 37′, the latter face being striated and giving two images. The third of the faces is also striated, and makes with *A*, an angle of 40° 12′. Following *y*, the first of the above faces, there are three others in direct succession; the first making with *A* an angle of 49° 9′ and 49° 35′: it may be treated as a composite face, partly *d* (101) and partly χ (30$\bar{2}$), one being in twin-orientation. The second face is poor and makes with *A* the angle 64° 34′. This differs a good deal from *Az* = 63° 36′, but no simple indices can be obtained to accord closely with the reading. The third face, which I take to be (001), is fairly large, and gives a good angle 79° 56′.

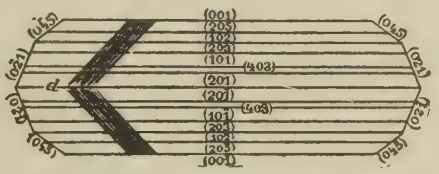

FIG. 3.—Baumhauer's crystal of Rathite (Crystal viii).

Hemipyramids, which I take to be *e* (322), *g* (111), and σ (122), are present on one side of one end; and at the other end there is a poor face parallel to σ. The angles given in the table are read from the yellow image *A*. It will be observed that they differ somewhat from the corresponding angles of wiltshireite, but not more so than happens with complex twins of other minerals, and more especially as the faces may be composite ones. Thus the face *e* to which I assign the symbol (322) may be λ (21$\bar{1}$) in twin-orientation; for the measured angle 50° 46′ is midway between *Ae* = 50° 14′, and *A*λ = 51° 4′. Measurement of cross-zones did not give satisfactory results, but served one good purpose. For in measuring [*md*] I perceived that the striae on one of the faces *m* were parallel (or nearly so) to the vertical wire, whilst on the opposite face they were nearly parallel to the horizontal wire. Again, on one of the large composite faces *f* (120), the striae on different laths are nearly at right angles to one another. By the aid of a two-circle goniometer I found the angle between the zones [010] and [01$\bar{1}$] to be 46° 53′, which agrees well with the 46° 56′ of wiltshireite. Again the angle

between the zones [01$\bar{1}$] and [001] was found to be 42° 57′; and computation of this angle from the triangles *Afσ* and *Amg* gives the same value.

If it be now accepted that the system of rathite is oblique, and that the variations in its angles from those of wiltshireite (regarded as its simple form) are due to the disturbance produced by complex twinning, we can compare my results with those of Professor Baumhauer and Mr. Solly in their memoirs (already cited) by supposing that the pinakoid {010} of the former and {001} of the latter are replaced by {$\bar{1}$04} of wiltshireite. The formulae of transformation of their symbols are the following (unaffected indices being those of wiltshireite):

Mr. Solly $h_{,} = 3k,\ k_{,} = 4h + l,\ l_{,} = 3l.$

Professor Baumhauer $h_{,,} = 20k,\ k_{,,} = 28l,\ l_{,,} = 5\,(4h + l).$

Lewis.	Solly.	Baumhauer.		
*100	010	001		
*010	100	100		
*$\bar{1}$04	001	010		
120	320	201		
*110	340	101		
*hk*0	3*k*·4*h*·0	*k*0*h*		
*20$\bar{1}$	073	0$\bar{4}$5		
302	078	045		
17·0·16	074	—		
101	053	0·28·25	nearly	0·11·10
30$\bar{2}$	05$\bar{3}$	0·28·25	,,	0·$\bar{1}\bar{1}$·10
10$\bar{1}$	01$\bar{1}$	0·28·15	,,	021
203	059	0·84·25	,,	0·$\bar{1}$7·5
**509	0·11·27	0·252·55	,,	0·$\bar{1}$4·3, or 092
001	013	0·28·5	=	
10$\bar{2}$	01$\bar{3}$	0·28·5		
11$\bar{1}$	11$\bar{1}$	20·28·15		
111	353	20·28·25		
322	35$\bar{3}$	20·28·25		

The faces which serve as basis of the transformation are those starred. The symbol (509) is not that of an observed face; but is that of a possible one making with (100) an angle of 79° 9′. Computation of the angles corresponding to the symbols in the two last columns will not agree exactly with those given by Messrs. Solly and Baumhauer; for the angles will be those of wiltshireite. In Mr. Solly's memoir (this Magazine, vol. xiii, p. 73) the table of his and Baumhauer's symbols does not in all cases give the true equivalents, but only near approximations with simple indices. Thus Solly's (190) is Baumhauer's (4·0·27) and not as stated (107); and Baumhauer's (045) should be (094), although in my transformation it is, as given by Mr. Solly, taken as (073).

Table of Angles observed on Wiltshireite and Rathite.

	Indices.	Computed.	Wiltshireite. Observed means.				Rathite. Observed means.		
			Crystal i.	Crystal ii.	Crystal iii.	Crystals iv & v.	Crystal vi.	Crystal vii.	Crystal viii.
	100 : 501	15° 46′		15° 16′		Crystal iv.			
	401	18 46		18 25					
h	301	23 59					23° 40′		
t	201	32 38	32° 36′			32° 14′	32 32		
ζ	302	39 22				39 19			
d	101	48 47½	48 47			48 47	48 48		
	405	53 27							
φ	102	61 57				61 52	61 47		
C	001	79 16	79 15			80 41	79 21		79° 56½′
ψ	$\bar{1}04$	88 58							
w	$\bar{1}02$	98 44							
u	203	105 0	104 12	104 51					
z	$\bar{1}01$	116 24½	116 33	116 29	116° 24′				
χ	302	130 1							
y	$\bar{2}01$	139 47½	139 46		138 56		139 42	139° 31′	139 48
	301	151 51							
θ	100 : 510	17 19	17 48	17 39	17 10			17 37	
p	920	19 6			19 7			19 17	19 59
	410	21 18				21 24		21 51	21 21
	720	24 1						24 35	
l	310	27 28	28 17	27 15	27 23		27 14	27 46	27 54
	520	31 57	31 52		31 50		32 15	32 27	32 14
r	210	37 56	38 35		37 57		38 14	38 24	38 24
	740	41 42			41 44				41 19
s	320	46 6		46 3	46 4	46 4	46 24	46 28	46 34½
	540	51 17					51 20	51 40	51 46
m	110	57 19		57 8	57 32	57 22	57 21	57 39	57 46
ω	340	64 18	64 15						
f	120	72 13		72 14	72 13	72 12	72 19	72 29	72 30
a	250	75 37			75 49				76 18
	140	80 53						80 22	81 4
k	100 : 522	37 33	38 7?						
δ	211	43 9	43 7						
e	322	50 14	50 7			50 12	50 7		50 46
g	111	59 7	59 10		59 5	59 2	58 53		59 29
	344	64 19				64 21			
σ	122	70 1	70 0		69 54	70 2	70 7		70 15
n	011	82 37½	82 38		82 36		82 29		
o	$\bar{1}22$	96 0	96 2		96 1		95 47		
p	$\bar{1}11$	108 44	108 39		108 46		108 50		
x	$\bar{3}22$	119 50			119 48				
λ	$\bar{2}11$	128 56	128 58		129 8				
κ	$\bar{5}22$	136 11	136 2		136 11				
i	$\bar{3}11$	141 56			142 0				

Table of Angles (*continued*).

Forms.	Indices.	Computed.	Wiltshireite. Observed means.				Rathite. Observed means.		
			Crystal i.	Crystal ii.	Crystal iii.	Crystals iv & v.	Crystal vi.	Crystal vii.	Crystal viii.
$A\mu$	100:31$\bar{2}$	53 29			53 33				
$A\eta$	52$\bar{4}$	59 29			59 21				
$A\pi$	21$\bar{2}$	66 21			66 20				
$A\epsilon$	32$\bar{4}$	74 0			74 7				
$A\Delta$	11$\bar{2}$	82 17			81 57				
$A\gamma$	01$\bar{2}$	99 29			98 51				
zn	$\bar{1}$01:011	56 40			56 36				
mn	110:011	47 14	47 17		47 20				
$m\Delta$	$\bar{1}$12	71 17							
$m\lambda$	21$\bar{1}$	35 9		35 3	35 9				
$m\mu$	31$\bar{2}$	50 10		50 4	49 57				
mz,	10$\bar{1}$	76 6		75 59	75 56				
$f\sigma$	120:122	40 42	40 37						40 39
$C\sigma$	001:122	46 2	45 47						46 26
Cf	120	86 44	86 34						87 5
Cf,	$\bar{1}\bar{2}$0	93 16							93 2
$s\kappa$	320:52$\bar{2}$	30 8		29 51	30 8				
$s\sigma$	122	42 58	42 54		42 54				
sz	$\bar{1}$01	107 57	107 50	108 7	108 2				
σs	122:$\bar{1}$01	64 59	64 55		65 5	Crystal v.			
yi	20$\bar{1}$:31$\bar{1}$	36 28			36 16				
ym	110	65 39			65 10				
mp	110:$\bar{1}$11	65 52			65 55	65°34′			
$p\mu$	$\bar{1}$11:3$\bar{1}$2	24 13			24 8				
py	20$\bar{1}$	48 29			48 49	48 18			
mg	110:111	36 24½			36 26				36 28
$m\Sigma$	11$\bar{2}$	53 56			54 22				
mC	001	84 14	84 19						84 40
mp,	11$\bar{1}$	40 54	40 50		40 25				
$m\Delta$	11$\bar{2}$	62 14	62 19		61 47				
C,Δ	00$\bar{1}$:11$\bar{2}$	33 32	33 26						
$p\pi$	$\bar{1}$11:$\bar{2}$12	18 10½	18 14*		18 7				
πz	$\bar{2}$12:$\bar{1}$01	25 36	25 28		25 37				
pz	$\bar{1}$11:$\bar{1}$01	43 46½	43 45		43 44				
pp,	$\bar{1}$11:$\bar{1}\bar{1}$1	87 33	87 29		87 31				
nC	011:001	46 26	46 29*						
γC	012:001	27 43½							
nn,	011:0$\bar{1}$1	92 52	92 52						

* As pointed out in the description of crystal i, these angles are a selection amongst a number of possible values.

OMMUNICATIONS FROM THE OXFORD MINERALOGICAL LABORATORY.

No. XXII.

rystallographic notes on Inosite, Potassium nitrate, and Urea nitrate.

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[Read March 21, 1911.]

(1) INOSITE.

RYSTALS of Inosite, $C_6H_6(OH)_6 . 2H_2O$, were first measured by Cloëtta,[1] and somewhat later by Zepharovich,[2] and by Lewis;[3] ey are monoclinic, and the elements adopted are those of Zephavich, viz., $a : b : c = 1{\cdot}0872 : 1 : 1{\cdot}5602$; $\beta = 111° 39'$. The observed ms on the crystals were {010}, {110}, {100}, {001}, {$\bar{1}$01}, {$\bar{2}$14}, 10}, and {410}, and it is seen that the form-development is of a newhat anomalous character, the indices of the last three forms being narkable for their complexity.

Now the observation of forms with relatively high indices is not unnmon, but as a rule they do not rank among the principal forms, ng of a subsidiary character and only developed on certain crystals. inosite, however, the form {210} is as well developed as {110}; ther, {$\bar{2}$14} is the only pyramidal form on the crystals, and, according Cloëtta, is the predominant form. What is equally significant is the t that simple forms like {111}, {$\bar{1}$11}, {$\bar{1}$01}, and {011} are not at represented. These considerations led Fedorov[4] to the conclusion t the directions hitherto chosen for the crystallographic axes in inosite

1. A. Cloëtta, Liebig's Annalen d. Chem., 1856, vol. xcix, p. 291.
2. V. v. Zepharovich, Sitzungsber. Akad. Wiss. Wien, 1868, vol. lviii, Abt. 2, 121.
3. W. J. Lewis, Phil. Mag., 1878, ser. 5, vol. v, p. 141; Proc. Cryst. Soc., 1882, ii, p. 51; Zeits. Kryst. Min., 1878, vol. ii, p. 190.
4. E. S. Fedorov, Zeits. Kryst. Min., 1903, vol. xxxviii, p. 327.

do not represent the real principal directions in the crystal. The form development on critical examination points to a hypohexagonal structur and he therefore proposed a new setting, which is undoubtedly far mo in accordance with the molecular structure, inasmuch as the forms thereb acquire simpler indices. When this new setting is adopted, howeve there is a certain hiatus in the form-development, for two or thre forms having simple indices have not been observed.

Professor Fedorov kindly suggested to the author that a variation the conditions of crystallization might lead to the development of th expected forms. The crystals hitherto investigated were crystallize from a cold solution, so it was decided to study the crystallization at higher temperature. A quantity of inosite was very courteously pu at the author's disposal by Dr. Hugo Müller, and crystals were obtaine by slowly cooling an aqueous solution which was saturated at about 60° The crystals were measured on the two-circle goniometer and two ne forms having very simple indices were observed. The three forms wit most complex indices previously observed were not at all developed, that the form-development of the author's crystals is nearly ideal an confirms the correctness of Fedorov's setting in a very conclusiv manner.

Adopting for the present the old setting, the forms observed by th author were: $b\{010\}$, $c\{001\}$, $q\{012\}$, $r\{\bar{1}01\}$, $s\{\bar{1}02\}$, and $p\{210\}$ the new forms are $q\{012\}$ and $s\{\bar{1}02\}$. The crystals were tabul parallel to $b\{010\}$, but the direction of elongation was the edge cb is shown in fig. 1. The zone cb was therefore set up as the prism-zo on the goniometer, and the readings of ϕ and ρ obtained do not hold f a crystal as generally set up with the edge am vertical. The theoretic values of the angles for a crystal set up in the former way have bee calculated from the elements of Zepharovich, and are given in the follow ing table:

Face.	ϕ (Azimuth).[1]			ρ (Polar Distance).		
	Observed Limits.	Mean.	Calculated.	Observed Limits.	Mean.	Cal lat
q (012)	49° 40′— 51° 52′	51° 10′	54° 3′	— —	—	
s ($\bar{1}$02)	89 35 — 90 0	89 54	90 0	42° 45′—44° 41′	43° 58′	47°
r ($\bar{1}$01)	89 28 — 90 55	90 14	90 0	15 32 —16 52	15 59	19
p (2$\bar{1}$0)	321 11 —323 14	322 20	323 51	33 51 —35 58	34 59	35

[1] Face of origin, the plane of symmetry b(010).

In some cases twinned crystals were observed with $c(001)$ as twin-plane, the forms developed being {010}, {012}, and {210}. Twinning on the same plane was previously observed by Zepharovich, but of course with a different form-combination.

It immediately follows from the large discrepancies between the mean observed and calculated values that the angles are not very trustworthy, and the material was re-crystallized many times in the hope of getting better developed crystals. The faces, with the exception of (010) which was used as a face of reference, were always rounded and the reflections on that account either very faint or, where they were bright, of a multiple character. Although so unsatisfactory, the readings are sufficiently

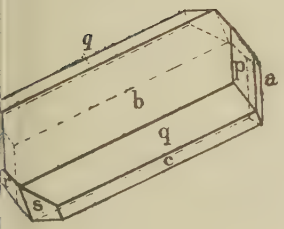

Fig. 1.—Crystal of Inosite.

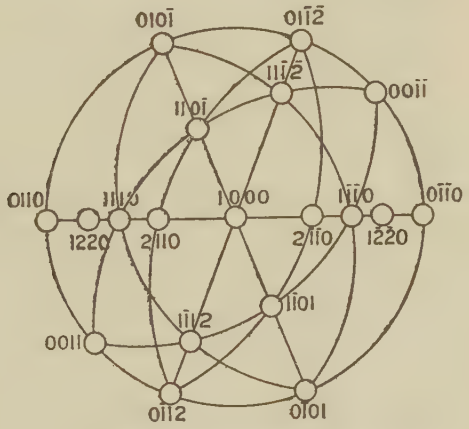

Fig. 2.—Stereographic projection, on the plane of symmetry, of the crystal-forms of Inosite. (The first index refers to the intercept on the dyad (hypohexagonal) axis of symmetry.)

good to determine the indices of the new faces; moreover, the extinction on the face b (010) with respect to the edges between it and the faces of the zone [010] in all cases was in accordance with the optical determination of Zepharovich. A stereographic projection of all the forms hitherto observed is given in fig. 2. The cleavage is perfect parallel to b (010).

In order to obtain the indices $(q_0q_1q_2q_3)$ in the hypohexagonal setting proposed by Fedorov from the indices $(p_1p_2p_3)$ with the old setting of Zepharovich, the following transformation equations are made use of:

$$q_0 : q_1 : q_2 : q_3 = 2p_2 : p_1 + p_3 : p_1 : -p_3.$$

For example, in the case of the face $(\bar{2}14)$, $p_1 = \bar{2}$, $p_2 = 1$, $p_3 = 4$; inserting these values in the above equation we obtain—

$$q_0 : q_1 : q_2 : q_3 = 2 \times 1 : \bar{2} + 4 : \bar{2} : \bar{4} = 2 : 2 : \bar{2} : \bar{4}$$
$$= 1 : 1 : \bar{1} : \bar{2} = (11\bar{1}\bar{2}).$$

It may be remarked that the first index q_0 refers to the principal direction in the crystal, namely the pseudo-hexagonal axis which coincides with the dyad axis of symmetry. The following are the indices according to the old and new settings for all the forms found by different observers, as well as the form $(21\bar{2}) = (1011)$ which has never been recorded:

Old setting:	(010)	(001)	(012)	($\bar{1}$01)	(100)	(21$\bar{2}$)
New setting:	(1000)	(010$\bar{1}$)	(110$\bar{1}$)	(00$\bar{1}\bar{1}$)	(0110)	(1011)
Old setting:	(210)	(10$\bar{2}$)	(110)	(21$\bar{4}$)	(410).	
New setting:	(1110)	(0$\bar{1}$12)	(2110)	(1$\bar{1}$12)	(1220).	

The forms are arranged in order of reticular density in the new setting, beginning with the plane of symmetry, which has the highest reticular density. It is seen from the table that the two new forms (012) and (10$\bar{2}$) possess a comparatively high position in the series, so that the combination of forms observed by the author approximates very closely to the ideal combination (i.e. a combination exhibiting faces of maximum reticular density). All that is required to make the combination ideal is the presence of the form $(21\bar{2}) = (1011)$ which has never yet been observed. Moreover, it is seen that Fedorov's setting is in harmony with the existence of a good cleavage parallel to the plane of symmetry, for the particles are most densely packed in this plane. With the old setting, on the other hand, the cleavage would be expected to be parallel to (001), for this would be the plane of maximum reticular density.

(2) The Rhombohedral Modification of Potassium Nitrate, and its Growth on Calcite.

Potassium nitrate crystallizes as a rule in orthorhombic crystals with a pronounced prismatic habit, but at higher temperatures the form is rhombohedral and isomorphous with that of sodium nitrate. The transition temperature has been variously determined by different observers and appears to be about 128° C. It was observed by Frankenheim that the rhombohedral modification sometimes appears from aqueous solutions at the ordinary temperature; this is very unstable and more or less rapidly passes into the stable orthorhombic form.

The author has, from time to time, endeavoured to obtain the rhombohedral form from crystallizing drops of solution with a view to determining whether it is capable of forming parallel growths on calcite. The unknown conditions for its appearance would seem to be difficult to obtain, for the most varied trials with different samples repeatedly failed to give the wished-for results. A solution was at last obtained which deposited rhombohedral crystals; qualitative analysis of the salt failed to point to the presence of any impurity—as, for example, sodium nitrate—which might conceivably be the cause of the appearance of the rhombohedral modification.

The rhombohedra which crystallize from drops of the solution are clear and very well defined. They are microscopically, both with regard to their optical and geometrical characters, indistinguishable from crystals of sodium nitrate. The birefringence is very strong and the rhombohedron angle has, according to Frankenheim, the value 73° 24′, which is very close to the value (73° 37′) for sodium nitrate.

After the growth of the rhombohedra has gone on for a little time, they rapidly lose their transparency and pass into a crystalline aggregate of the stable orthorhombic modification: the change is probably always brought about by contact with a small orthorhombic crystal, but the latter is in many cases so small as to be invisible. The belief that the change is actually brought about by nuclei of the stable modification is supported by the observation that the transformation of all the rhombohedra is not effected simultaneously, but goes on through the drop in a progressive manner at short intervals.

Attempts were made to obtain parallel growths on calcite by allowing drops of the saturated solution to crystallize on a fresh cleavage surface. The rhombohedra never failed to make their appearance, but no definite orientation was traceable: the edges of the rhombohedra were as a rule inclined at various angles to the edge of the calcite. After standing for some time, the transformation took place into the stable modification.

It may, therefore, be concluded that the rhombohedral modification of potassium nitrate is incapable of forming a parallel growth on calcite. Unfortunately, it has not been found possible to determine the specific gravity of this modification, owing to its instability, and the molecular volume therefore remains unknown. The author's previous work on isomorphous series, however, enables one to predict that the molecular volume should be about six units higher than that of sodium nitrate, which itself is slightly higher than that for calcite. The molecular volume, then, of rhombohedral potassium nitrate and calcite must show

a considerable difference, and on this account the experimental results were not wholly unexpected.

(3) Urea Nitrate, and its Optical Behaviour in Crystallizing Drops.

This substance ($CO(NH_2)_2 \cdot NO_3H$) has been the subject of repeated investigation. The crystals, which are really monoclinic, are almost invariably twins; this explains why Marignac,[1] who was the first to measure the substance, came to the conclusion that it is orthorhombic. A little later von Lang[2] expressed the opinion that the crystals might be monoclinic; and he determined the optical axial plane to be the plane of symmetry and the first positive mean line to be practically perpendicular to what was taken to be the basal plane, so that optically

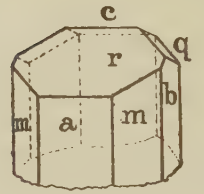

Fig. 3.—Simple crystal of Urea nitrate.

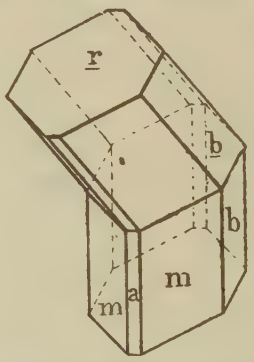

Fig. 4.—Twinned crystal of Urea nitrate. (Twin-plane r (101).)

too the crystals simulate orthorhombic symmetry. Gaubert[3] showed that the crystals are really twins on the basal plane.

It might be said that urea nitrate has already been sufficiently well investigated, but all the above observers failed to obtain any other forms except those lying in the prism-zone and the form (101), hitherto always held to be the basal plane, so that it was not possible to determine the ratio of the axes $c : b$. After many fruitless endeavours, the author succeeded in obtaining a crop of crystals which exhibited two new forms—$c(001)$ and $q(011)$. The former is taken to be the new basal plane, the old basal plane becoming (101).

[1] J. C. G. de Marignac, Mém. Soc. Phys. Genève, 1855, vol. xiv, p. 284.
[2] V. von Lang, Sitzungsber. Akad. Wiss. Wien, 1862, vol. xlv, p. 118.
[3] P. Gaubert, Compt. Rend. Acad. Sci. Paris, 1907, vol. cxlv, p. 378.

The crystals were obtained by slowly cooling an aqueous solution. They are very soft and flexible, so that great care has to be taken in drying the crystals.

System: Monoclinic.

Ratios of the Axes: $a:b:c = 0{\cdot}9965:1:0{\cdot}9142$; $\beta = 75° 2\frac{1}{2}'$.

Forms: $r\{101\}$, $b\{010\}$, $m\{110\}$, $c\{001\}$, $a\{100\}$, $q\{011\}$.

A typical crystal showing the new forms $c\{001\}$ and $q\{011\}$ is shown in fig. 3; these crystals were mostly untwinned. All the other crops examined were twins of the usual type with $r(101)$ as twin-plane (fig. 4). It may be observed that it is difficult to say without actual measurement on the goniometer whether a given crystal is a twin or is a single crystal with the two new forms, since on reflection across the twin-plane (101) the faces (100) and (110) approximately come into the position of the forms (001) and (011) on an untwinned crystal. It is therefore possible that crystals having the forms (001) and (011) have been previously obtained by other observers, but have been regarded as due to twinning.

The following are the results of the measurements obtained on the two-circle goniometer:

ace.	No.	ϕ (Azimuth).			ρ (Polar Distance).		
		Observed Limits.	Mean.	Calculated.	Observed Limits.	Mean.	Calculated.
110)	8	46° 1′— 46° 9′	*46° 5′	—	— —	—	—
100)	2	— —	90 0	90° 0′	— —	—	—
101)	2	89 47 — 90 14	90 1	90 0	— —	*34° 18′	—
001)	2	269 47 —270 14	270 1	270 0	14° 57′—14° 58′	*14 57½	—
011)	3	342 56 —343 30	343 13	343 42	43 12 —43 48	43 33	43° 36′

A control reading was taken of the angle (101):(011):

Found 60° 34′, Calculated 60° 43′.

In order to transform the above setting into the one suggested by Fedorov, the following transformation equation must be used: $q_1:q_2:q_3 = p_2:-p_1:p_3$. Cleavage: $r(101)$ perfect. Optics (von Lang): Birefringence, negative; axial plane, (010); acute bisectrix perpendicular to $r(101)$; $2E = 21° 10'$ (red), 23° 10′ (yellow), 24° 30′ (green), and 26° 30′ (blue).

Optical Behaviour in Crystallizing Drops of Urea Nitrate.

Well-defined, microscopic crystals of urea nitrate are obtained by placing a drop of warm, saturated aqueous solution on a microscope-slide, and the optical properties are of such a nature as to make the substance most useful for demonstration purposes. The crystals are practically always reflection-twins on $r(101)$, and they always lie either on the twin-plane or on the plane of symmetry. Since the optical properties of the crystals as viewed in these two positions are wholly dissimilar, it will be convenient to treat the two cases quite separately.

(1) *Crystals resting on the plane of symmetry* $b(010)$.—In this position the twinning is immediately evident by the re-entrant angles. Generally the crystals are contact-twins with (101) as both twin- and composition-plane (fig. 5 *a*); sometimes, however, interpenetration-twins occur (fig. 5 *b*), and occasionally the twinning is further repeated. Since the acute bisectrix is normal to the twin-plane $r(101)$, the two parts of the twin extinguish simultaneously, namely when the trace of the twin-plane is parallel to the plane of vibration of either nicol, that is, to either of the cross-wires in the eye-piece of the usual microscope.

On rotating the crystal and viewing with the polarizer without the analyser, the crystal experiences a remarkable change of relief; when the trace of the twin-plane is parallel to the vertical cross-wire (i. e. when the crystal is in the position of fig. 5 *a*) the relief is so low that it is very difficult indeed to make out the crystal outlines, whilst in the position perpendicular to this, the relief is at a maximum and is extremely high. On rotating through 360° there are two positions of minimum and two of maximum relief. The profound change of relief is only noticeable while the crystal is immersed in the drop of concentrated solution; when the drop has dried up, the outlines of the crystal no longer vary in sharpness on rotation. It is evident that in the position of low relief (which coincides with a position of extinction under crossed nicols) the refractive index of the solution must be of about the same value as that of the ray traversing the crystal. According to von Lang's determination, the latter is the ray of minimum refractive index α. On rotating the crystal through 90° the ray traversing the crystal now has the value γ, which is much greater than α, and the crystal on this account stands out in bold relief.

(2) *Crystals resting on the twin-plane* $r(101)$.—In this case it is not possible to recognize the twins either geometrically or optically, for no re-entrant angles are visible, and, moreover, since the acute bisectrix

is perpendicular to the twin-plane, the twinned crystal behaves optically as a single crystal. The appearance of such a twin is shown in fig. 5 *c*. The crystals extinguish uniformly parallel and perpendicular to the edge *rb*. In convergent light the characteristic biaxial interference-figure is visible: provided a sufficiently thin crystal be taken, the figure is as clear as in a prepared and mounted section and the optical characters can be easily made out.

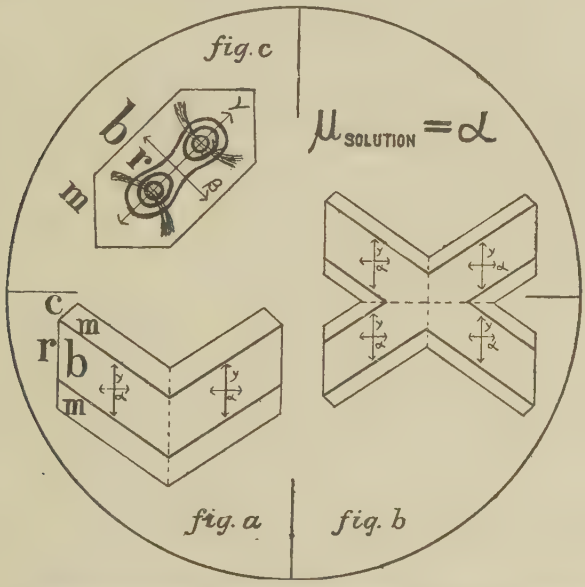

FIG. 5.—Growing crystals of Urea nitrate as seen under the microscope; showing a variation in optical character when viewed in different directions.

On examination with the polarizer there is no marked change on rotation, the crystal permanently remaining in high relief. This is what would be expected, for the two rays which traverse the crystal are the principal rays, having respectively the indices of refraction β and γ (cf. fig. 5 *c*). Now since the optic axial angle is small and the birefringence is negative, it follows that the β index is very close in value to the index γ, and both β and γ differ greatly from α, the last being approximately the value of refractive index for the solution.

The accuracy of the foregoing observations with respect to the orientation of the microscopic crystals has been confirmed by taking large crystals, the orientation of which had been first determined by measure-

ment on the goniometer, and then observing them under the microscope both in air and also when immersed in a saturated aqueous solution.

Summary of Results.

1. The re-investigation of inosite has led to the observation of a new and very simple form-combination which confirms the correctness of the setting proposed by Fedorov.

2. The rhombohedral modification of potassium nitrate fails to give a parallel growth on a fresh cleavage of calcite.

3. The crystallographic constants of urea nitrate have been fully determined. Growing crystals of this substance under the microscope afford good illustrations of change of relief, twinning, and a very clear biaxial interference-figure.

Prehnite from the Lizard district, Cornwall.

By Arthur Russell.

[Read June 13, 1911.]

HITHERTO the mineral prehnite has been recorded from one locality only in Cornwall, namely, in the cliffs between Wheal Cock and the Crowns Rock, Botallack, St. Just.[1] It occurs there as pale-green, globular aggregates composed of indistinct, curved crystals, and forms veins traversing a narrow strip of greenstone which has intruded itself through the granite mass; associated minerals are stilbite and axinite.

In the summer of 1910 the writer collected several crystallized specimens of this mineral at Parc Bean Cove, Mullion, the locality from which Dr. J. S. Flett and Mr. W. F. P. McLintock obtained the fine crystallized specimens of datolite, recently described by the latter.[2] The prehnite occurs here in two distinct and somewhat unusual types of crystals—tabular and prismatic. In both cases the crystals form a crust on a dense, blackish-grey hornblende-schist. The specimens were obtained from a large block of the hornblende-schist at the base of the cliff, close to the spot yielding the datolite. For the identification of the forms of the crystals the writer is indebted to Mr. L. J. Spencer, who kindly undertook the necessary measurements.

The tabular crystals are flattened parallel to $c\{001\}$, and measure up to 4 mm. along the side; for the most part they are attached to the matrix with the faces *o* uppermost. They are of a dirty greenish-white colour and are somewhat corroded, probably from the action of the sea-water to which they were evidently at times exposed. The following forms are present: $c\{001\}$, $n\{302\}$, $o\{061\}$ (fig. 1). The cleavage parallel to *c* is distinct and shows a pearly lustre. The crystals are optically positive with strong double refraction, and the optic axial plane is parallel to (010). The specific gravity is 2·88, and the hardness

[1] Joseph Carne, 'On the mineral productions, and the geology of the parish of St. Just,' Trans. R. Geol. Soc. Cornwall, 1822, vol. ii, pp. 290–358 (Prehnite on p. 310). Compare A. Russell, Mineralogical Magazine, 1910, vol. xv, p. 379.

[2] W. F. P. McLintock, 'On datolite from the Lizard district, Cornwall,' Mineralogical Magazine, 1910, vol. xv, pp. 407–414.

about 6. A qualitative chemical examination revealed the presence of silica, alumina, calcium, and a little water.

The prismatic crystals, of which only one specimen was found, form a thin crust which is in part botryoidal. They are of a dirty white colour and measure about 1 mm. in length. They are elongated in the direction of the a-axis, and exhibit the forms $a\{100\}$, $c\{001\}$, $m\{110\}$, $o\{061\}$, $u\{301\}$ (fig. 2).[1] The faces of c and o are striated parallel to the mutual intersections. The physical, optical, and chemical properties are precisely similar to those of the tabular crystals.

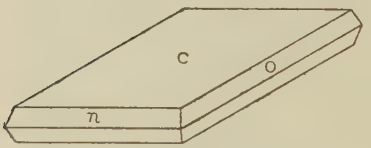

Fig. 1.

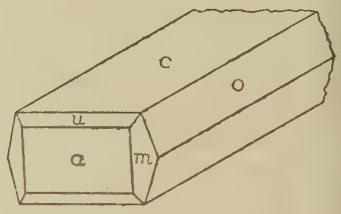

Fig. 2.

Crystals of Prehnite from Cornwall.

Specimens of a white mineral, forming a stalactitic and botryoidal crust on the hornblende-schist, were also obtained from the foot of the cliff above mentioned. This crust consists of a mass of minute, tabular crystals, rectangular in outline, of which, however, it was impossible to determine the exact form. Some of these crystals are opaque, whilst others are transparent at the edges and milky in the centre. On one specimen these same crystals are aggregated in the form of hollow rhombohedra, reaching $3\frac{1}{2}$ mm. across, the broken edges of which present a fibrous structure; these are probably pseudomorphous after calcite. The specific gravity is about 2·61, and the hardness $5\frac{1}{2}$. The mineral contains silica, alumina, calcium, and water, and therefore appears to be prehnite, although the specific gravity is unusually low for that mineral.

Natrolite occurs upon the surface of the mineral just described as bundles of colourless, prismatic crystals up to $1\frac{1}{4}$ mm. in length. These crystals are considerably etched and the forms therefore difficult to determine; they appear, however, to be similar to those occurring on the datolite as described by Mr. McLintock.

[1] The form $u\{301\}$ has hitherto been recorded only on crystals of prehnite from Josvas copper mine, Julianehaab district, Greenland.—O. B. Böggild, 'Mineralogia Groenlandica,' 1905, p. 292.

On the frequent occurrence of Ankerite in coal.

By T. Crook, A.R.C.Sc. (Dublin), F.G.S.

Scientific and Technical Department, Imperial Institute.

[Read November 14, 1911.]

Mode of occurrence.—There occurs frequently in coal a white carbonate which, when it is referred to at all by scientific writers on coal, is usually described as calcium carbonate. It occurs as a rule in the form of thin layers infilling the joint-cracks which lie normal to the bedding-planes, though at times it may be seen infilling other divisional planes which may cut across the bedding obliquely.

The layers flake off very readily, and show in a well-marked way the impress of the joint-faces on which they have been deposited. They are planes of weakness in the coal; and blocks in which they are well developed yield with comparative readiness to mechanical strain and the influence of the weather.

Specimens of coal sometimes contain as much as from 5 to 10 per cent. or more of this mineral impurity, in the form of thin parallel layers. The average thickness of these layers is less than 1 mm., but occasionally they are much thicker. Some varieties of London house-coal contain the mineral in abundance, and one may safely say that many tons of this carbonate are placed weekly on London fires.

Identity of the mineral.—Having for some time noticed an abundance of the mineral in my house-coal (stated by the coal-merchant to come from Leicestershire), I was curious to know the exact identity of the mineral, and to what extent, if any, it varied in character. This curiosity was stimulated by the fact that, although it appeared in all cases to be a carbonate, very little of it had the properties of calcium carbonate. It showed little or no effervescence in a cold dilute solution of hydrochloric acid, but dissolved readily on warming. The solution thus obtained was colourless, but gave a strong ferrous reaction, suggesting the presence of far too much iron for an ordinary dolomite. In this respect, indeed, its behaviour was more like that of siderite. The

presence of ferrous iron explains the fact that the mineral turns brown as a result of weathering.

A determination of the specific gravity, using methylene iodide and a Westphal balance, gave the result 3·01. The specific gravity proved to be fairly constant, and suggested that the mineral was probably ankerite. This view was confirmed by the fact that, though white, the mineral is weakly magnetic, and when heated in a reducing flame it becomes black and strongly magnetic. Conclusive proof that the mineral is ankerite is provided by an analysis, given below, of crystalline fragments.

Crystalline condition of the ankerite.—The mineral has not crystallized very freely, as is shown by the granular condition of the layers. The clearer layers show a sort of pearly lustre. The stoutly developed grains exhibit curved cleavage-faces resembling those frequently seen in dolomite and siderite.

The granular condition is well seen when the clearer layers are examined microscopically. Between crossed nicols the individual grains show a lack of uniform extinction, a fact in keeping with the curvature of the cleavage-faces. One also sees, between crossed nicols, that the grains as a whole tend to arrange themselves in radial aggregates. The thicker layers, in some cases, show a fibrous structure.

Chemical composition.—The crystalline ankerite, having a specific gravity 3·01, gave the following analysis (see also p. 222):

		per cent.
CaO	...	30·75
FeO	...	15·33
MnO	...	1·15
MgO	...	8·96
CO_2	...	43·99
		100·18

Allocating to the lime, ferrous oxide, magnesia, and manganous oxide the amounts of carbon dioxide required by them, and calculating the molecular ratios, we get:

		per cent.		molecular ratios.
$CaCO_3$	...	54·91	...	0·549
$FeCO_3$	...	24·70	...	0·213
$MnCO_3$	...	1·86	...	0·016
$MgCO_3$	...	18·84	...	0·224

This result shows a molecular excess of calcium carbonate over that required by the formula $2\,CaCO_3 . Fe(Mn)CO_3 . MgCO_3$, which is the one

usually taken as representing normal ankerite. The amount of this excess corresponds to about 9·6 per cent. of calcium carbonate. One naturally inquires, therefore, as to the condition in which this excess of calcium carbonate is present.

The association of calcite with the ankerite (see below) gave rise to the impression that, in spite of the fairly constant density, the excess of calcium carbonate might be present as definite grains of calcite mixed with the ankerite. Microscopical examination, however, gave no encouragement to this view. To test this point, the ankerite layers were immersed in a solution of logwood and aluminium chloride, calcite being used for control, and no part of the ankerite layers took on the stain. Following on this result, several partial analyses of the ankerite from various specimens were made. The results proved conclusively that the chemical composition of the mineral in that particular lot of house-coal was practically constant, as its fairly constant specific gravity led one to expect.

From these results, therefore, it may be safely inferred that the excess of calcium carbonate over the amount required to form normal ankerite is present in a state of intimate molecular admixture; and that the mineral in this case may be regarded as consisting of about 9·6 per cent. of calcite isomorphously intergrown with about 90·4 per cent. of normal ankerite.

Minerals associated with the ankerite.—

Calcite.—The amount of free calcite present in the house-coal examined is comparatively small. Moreover, there is no difficulty in distinguishing it from the ankerite. The calcite is characterized by the fact that it frequently forms highly transparent layers. It has evidently crystallized very freely as compared with the ankerite, and, unlike the latter, it forms non-granular layers, in which the cleavages are seen to be continuous over comparatively large areas. The calcite is typical in all its characters, and appears to be quite pure.

Occasionally, calcite and ankerite are seen in the same layer; but in such cases of this as were observed, there was a sharp line of demarcation between the calcite and ankerite portions of the layer. As a rule, however, the calcite and ankerite occur in independent layers.

Zinc-blende and galena.—These two minerals occur associated with the ankerite layers. In the specimens examined the zinc-blende was present in comparatively much larger quantity than the galena. One small specimen of coal, $5 \times 3\frac{1}{2} \times 1\frac{1}{2}$ cm. in size, showed the association of ankerite, calcite, iron-pyrites, and zinc-blende. The layer of zinc-blende

in this specimen occupied an area of 2 × 1 cm., and was about 0·25 mm. thick.

Barytes.—A considerable amount of this mineral occurs scattered through the ankerite layers in the form of crystalline plates; and these plates apparently occupy the entire thickness of the layers. On coarsely crushing about 30 grams of the ankerite, it was found that about 1·2 grams (i. e. about 4 per cent.) of the crushings sank in methylene iodide of maximum density. This 1·2 grams consisted almost entirely of plates of barytes, together with a few grains of zinc-blende, galena, and iron-pyrites. The plates of barytes are clear and transparent, but contain numerous lines of inclusions.

Gypsum was not observed in any of the specimens examined. Ordinary dolomite was looked for, but not found.

Specimens obtained from various coal-fields.—The mineralogy of house-coal as outlined above having proved so interesting, it seemed worth while to find out a few definite localities where ankeritic coal occurs. Specimens were obtained from the following sources [1]:

Collins Green Colliery, Newton-le-Willows, Lancashire.

Haydock Collieries, near St. Helens, Lancashire.

Allerton Bywater Collieries, Castleford, Yorkshire.

Pleasley Collieries, near Mansfield, Nottinghamshire.

Gwaun-cae-Gurwen Colliery, Llanelly, South Wales.

Donisthorpe Colliery, Ashby-de-la-Zouch, Leicestershire.

In all these specimens, white layers of ankerite were present as infillings of the joint-cracks. In the Pleasley specimen, which was one of cannel-coal, calcite predominated over the ankerite, but in the other specimens calcite was absent, or present only in small amount. Specific gravity determinations made on crystalline fragments of the ankerite in various specimens gave results ranging from 3·01 to 3·05.

In the Collins Green specimen, small crystalline fragments, free from impurity, had a specific gravity 3·05. An analysis of the ankerite of this specimen gave the following result:

		per cent.		molecular ratios.
$CaCO_3$	...	51·26	...	0·513
$FeCO_3$	...	25·21	...	0·217
$MnCO_3$	...	1·46	...	0·013
$MgCO_3$	...	22·55	...	0·268
		100·48		

[1] I am indebted to the various colliery proprietors for kindly sending specimens. For the Llanelly and Ashby specimens, I have to thank Mr. F. H. Butler and Mr. L. F. Wallis respectively.

The composition in this case corresponds very closely to that of normal ankerite.

The abundance of ankerite in many varieties of London house-coal, and its proved occurrence in specimens from the Lancashire, Yorkshire, Midland, and Welsh coal-fields, indicate that the mineral has a wide distribution in coal.

In accounting for the origin of these ankeritic infillings in the joints of the coal, one thinks naturally of the abundance of carbonates of calcium, iron, and magnesium in the strata overlying the coal-seams, and especially those of the coal-measures themselves. Moreover, barytes, zinc-blende, and galena are known to be freely disseminated through the iron-ores of the coal-measures.

The mode of occurrence and the overwhelming preponderance of ankerite and calcite among the minerals occurring in the joints of the coal point to the immediate origin of these minerals by downward infiltration, i. e. by deposition from solutions which have traversed the strata overlying the coal-seams.

Summary.

The white layers which occur frequently as infillings of joint-cracks in English coal are miniature mineral-veins. Though averaging less than 1 millimetre in thickness in ordinary specimens, these veins are in many cases very numerous, and their presence constitutes an important feature in the composition of the coal. As a rule, the dominant mineral is ankerite, which may be normal in composition (i. e. correspond to the formula $2\,CaCO_3 . Fe(Mn)CO_3 . MgCO_3$), or may contain a small excess of calcium carbonate, apparently in the form of an isomorphous growth. Calcite also occurs, and is sometimes the dominant mineral. The other associated minerals are iron-pyrites, barytes, zinc-blende, and galena.

On Strüverite from the Federated Malay States.

By T. Crook, A.R.C.Sc. (Dublin), F.G.S., and S. J. Johnstone,
Scientific and Technical Department, Imperial Institute.

[Read November 14, 1911.]

General remarks.

THE mineral dealt with in this paper was sent for examination to the Imperial Institute by Mr. J. B. Scrivenor, Government Geologist to the Federated Malay States. It occurs on the river Sebantun, about half a mile above Salak North village, Kuala Kangsar district, Perak. The ground on which it was obtained was held on a tin-mining lease, but had to be abandoned owing to the presence of the unknown mineral, which rendered mining unprofitable.

Mr. Scrivenor has ascertained that the locality is occupied by a small alluvial flat, that the mineral in question forms the bulk of the concentrate obtained from the alluvium, and that cassiterite, monazite, topaz, tourmaline, zircon, and iron-pyrites also occur. The mineral was originally supplied to Mr. Scrivenor by Mr. R. L. Corbett, who stated that he had obtained it by magnetic separation with a Wetherill machine, using a current of from 70 to 75 volts and 10 to 14 amperes.

As received at the Imperial Institute, the sample consisted of coarse angular grains, four or five millimetres in diameter. They appeared to consist entirely of a lustrous, black mineral. On looking over the specimen with a lens, however, some grains of a more brownish appearance could be picked out, and these proved to be cassiterite. Occasional particles of quartz were also observed to be intimately associated with the black, lustrous grains.

A preliminary analysis of the specimen indicated that titanium, tantalum, and iron were the essential ingredients. This composition, taken in conjunction with the physical characters of the mineral, led to the conclusion that we were dealing with a specimen of strüverite, as defined by Drs. Prior and Zambonini.[1] The analytical difficulties,

[1] G. T. Prior and F. Zambonini, 'On strüverite and its relation to ilmenorutile,' Mineralogical Magazine, 1908, vol. xv, pp. 78–89.

however, made the satisfactory chemical proof of this a very tedious piece of work.

Physical characters.

In the mass, the mineral is black and has a somewhat lustrous appearance. The specific gravity, determined on an amount weighing about 13 grams, which had been freed as far as possible from fragments of cassiterite, was found to be 5·30. The streak is not quite black, but has a somewhat greenish tint. This feature suggested the probability that the mineral was not likely to be quite opaque in microscopic splinters.

An optical examination of the fine crushings in this particular case gave interesting results. As far as can be judged from the appearance of the small particles obtained by fine crushing, the mineral seems to be homogeneous. These particles are not opaque, and they show strong pleochroism. Examined with one nicol, most of the thin flakes show a change from brownish-yellow to dull bluish-green on rotating the nicol. These flakes are birefringent, and compensate with a gypsum-plate when the fast vibration-trace of the plate lies along the maximum-absorption vibration-trace of the flake. Occasionally flakes are observed which show only the brownish-yellow colour on rotating the nicol, and these act isotropically. The optical behaviour thus suggests that the mineral is uniaxial, and on this assumption the pleochroism for the thinnest flakes may be defined thus: o = brownish-yellow, e = dull bluish-green. Thicker flakes show a change from brown to black, somewhat resembling that of brown tourmaline, but in the reverse sense, the ordinary ray being less absorbed.

In describing the physical characters of strüverite from Piedmont, Zambonini states that the mineral is opaque even in the thinnest flakes. His description of the mineral powder as 'grey-black', however, may be taken as an indication that the mineral is not quite opaque. In a recently published paper by Hess and Wells,[1] Hess states that the strüverite of South Dakota is opaque; but he describes the powder as having a slightly greenish tinge, from which we may perhaps infer that a closer examination of microscopic flakes would reveal optical characters somewhat resembling those of the Perak specimen.

In this connexion it is interesting to note that the Norwegian ilmenorutile shows a pleochroism closely resembling that of strüverite.

[1] F. L. Hess and R. C. Wells, 'An occurrence of strüverite,' Amer. Journ. Sci., 1911, ser. 4, vol. xxxi, pp. 432–442.

Further, as one would expect, flakes of ilmenorutile are more transparent so much so, that flakes showing a good uniaxial figure, of positive sign can be obtained without difficulty.

Numerous attempts were made to obtain a definite uniaxial figure with the Perak strüverite, but the results were inconclusive, owing to the less transparent nature of the flakes. The optical behaviour of strüverite, however, as outlined above, indicates clearly that it also is positive.[1] In view of Prior's suggestion that ilmenorutile and strüverite are solid solutions of mossite and tapiolite respectively, in rutile, it is interesting to note that these minerals are both optically positive, and that the ordinary ray in each case is less absorbed than the extraordinary. In these respects they resemble rutile.

Chemical analysis (S. J. J.).[2]

A preliminary analysis of the mineral showed that it is completely soluble in 5 per cent. sulphuric acid after fusion with potassium hydrogen sulphate; and almost completely soluble in concentrated sulphuric acid after digesting for several days. Titanium, tantalum, and iron appeared to be the chief ingredients; but tin, niobium, and silica were also present. Calcium, magnesium, aluminium, chromium, uranium, tungsten, vanadium, zirconium, cerium and its allies, and thorium were proved to be absent.

By quantitative analysis the following results were obtained:

TiO_2	45·74 per cent.
Ta_2O_5	35·96
Nb_2O_5	6·90
FeO	8·27
MnO	trace
SnO_2	2·67
SiO_2	0·20
H_2O at 105° C. ...	0·08
H_2O above 105° C. ...	0·42
	100·24

[1] As indicated by compensation with a gypsum-plate, the maximum-absorption vibration-direction is that of the slow ray; and as indicated by the pleochroism it is also the vibration-direction of the extraordinary ray.

[2] My thanks are due to Mr. J. Shelton, A.I.C., Assistant in the Scientific and Technical Department of the Imperial Institute, for valuable assistance rendered in connexion with the analysis of strüverite.—S. J. J.

The analysis was made as follows :—The mineral was finely ground and dissolved by heating for several days with hot concentrated sulphuric acid, allowing to cool, and pouring into a large bulk of water. There remained only a slight amount of insoluble residue, which consisted of stannic oxide and silica. A more rapid method of solution is to fuse the mineral with potassium hydrogen sulphate and then to dissolve the melt in 5 per cent. sulphuric acid containing a few drops of perhydrol.

The insoluble residue was reduced in hydrogen, and the tin and silica separated in the usual way.

The sulphuric acid solution was diluted, nearly neutralized with dilute ammonia, and acidulated with hydrochloric acid, and the tin precipitated by passing a current of hydrogen sulphide for some time. The precipitated stannic sulphide contained a small amount of titanium, from which it was freed by treatment with ammonium sulphide and re-precipitation with acid. The matter insoluble in ammonium sulphide was fused with potassium hydrogen sulphate and added to the hydrogen sulphide filtrate.

The stannic sulphide precipitate, together with that obtained from the insoluble residue, was oxidized with nitric acid, ignited, and weighed as stannic oxide. The quantities of stannic oxide found in two determinations by this method were 2·63 and 2·71 per cent. A check determination of the tin made by fusing the mineral with potassium hydrogen sulphate, dissolving in 5 per cent. sulphuric acid, adding a few grams of tartaric acid, and passing hydrogen sulphide, gave 2·68 per cent. of stannic oxide.

The filtrates from the hydrogen sulphide precipitation were nearly neutralized, a considerable excess of sodium thiosulphate added, and the whole boiled for about twenty minutes. The precipitate, which contained all the titanium, tantalum, and niobium, together with traces of iron, was freed from the latter impurity by dissolving in fused potassium hydrogen sulphate and re-precipitation as thiosulphate. The iron was obtained from the filtrates by boiling with excess of ammonia, filtering, and re-precipitating as acetate and finally as hydroxide. The iron was weighed as ferric oxide, the gravimetric determination being checked volumetrically by titration with potassium permanganate.

Several methods were tried for the separation of tantalic and niobic oxides from the titanium dioxide. Amongst these may be mentioned the following:

(*a*) The fractional crystallization of the acid potassium fluorides (Marignac method). This was found to be unsatisfactory, owing to the

complicating influence of the titanium salt, which interferes with the separation of the tantalic and niobic salts.

(*b*) Fusion with potassium carbonate at a high temperature was also tried, but although the chief part of the tantalic and niobic oxides was soluble, varying amounts of titanium also passed into solution. The addition of potassium nitrate to the melt seemed to intensify rather than diminish this difficulty.

The following was found to be the most satisfactory method to adopt. The well-washed thiosulphate precipitate was ignited and ground with about its own weight of pure sugar-carbon, transferred to a small porcelain boat, and heated to a high temperature in a Jena-glass tube in a current of chlorine which had passed through carbon tetrachloride. The temperature of the tube, excluding the portion containing the boat, was maintained at about 70° C., and by this means the less volatile tantalum and niobium chlorides were condensed practically free from titanium. The titanium chloride passed over and was caught by a series of wash-bottles containing water; it was found impossible to condense the titanium chloride quite completely by these wash-bottles. By repeating the distillation twice on the more volatile portion, almost complete separation of the tantalum and niobium from the titanium could be effected. The first distillation separated 93 per cent. of the total tantalic and niobic oxides found. The trace of manganese present in the mineral remained in the boat. The chlorides of tantalum and niobium were removed from the tube with the aid of strong hydrochloric acid, precipitated as hydrates, washed, ignited, and weighed.

This method is essentially similar to that adopted by Wells in separating titanium from tantalum and niobium. The use of carbon tetrachloride alone, as suggested by Wells, was found to be less satisfactory than the method we adopted.

A qualitative test for niobium in the above precipitate by the Giles[1] method indicated that this element was present in small quantity. An estimation of the niobium by the Metzger-Taylor[2] method of reduction with zinc and titration with potassium permanganate gave 6·9 per cent. of niobic oxide. (The factor used was 1 c.c. N/10 $KMnO_4$ = 0·00708 gram Nb_2O_5.) The tantalum and niobium of another portion of the mixed oxides, which had been separated from the titanium as above, were separated by the Marignac method. By this means the quantity

[1] W. B. Giles, Chem. News, 1907, vol. xcv, p. 37.

[2] F. J. Metzger and C. E. Taylor, School of Mines Quarterly, New York, 1909, vol. xxx, p. 323.

of niobic oxide found was 7·2 per cent. This result is probably slightly in excess of the quantity actually present, owing to the temperature of the experiment being rather high.

The chlorides which had passed over into the wash-bottles (chiefly titanium chloride) were precipitated by thiosulphate, fused with potassium hydrogen sulphate, the melt dissolved in 5 per cent. sulphuric acid, and the titanium and any tantalum and niobium present estimated gravimetrically as oxide. The titanium was estimated volumetrically by the following process: An aliquot part of the sulphuric acid solution was reduced with zinc and then titrated against N/20 ferric alum solution in an atmosphere of carbon dioxide, using ammonium sulphocyanide as an indicator. The ferric alum solution had been previously standardized against pure titanium sulphate.

The results obtained by the two methods showed that the solution obtained in the wash-bottles contained a small percentage of tantalum and niobium, which varied in amount but did not exceed 2 per cent. In the analysis recorded, this difference amounted to 0·98 per cent., and this quantity was divided proportionately between the niobic and tantalic oxides already found.

A direct estimation of the titanium was made by fusing a fresh portion of the mineral in potassium hydrogen sulphate, and, after removing the stannic oxide, estimating the titanium volumetrically by the process given above. An allowance was made for the niobium already found to be present. The titanium dioxide found in this way amounted to 45·74 per cent. The ferrous iron present was estimated by digesting the finely-ground mineral with 50 per cent. sulphuric acid in a sealed tube at 200° C. for several weeks and titrating with standard potassium permanganate.

The presence of scandium in strüverite.—Professor A. Fowler, F.R.S., kindly undertook to examine the mineral spectroscopically, and found that it yielded the spectrum of scandium. This is of considerable interest, in view of the rarity of that element, and the fact that strüverite has some features in common with 'wiikite'. The latter was found by Sir William Crookes to contain more scandia (1·17 per cent.) than any other mineral, and had tantalic oxide, titanium dioxide, ferrous oxide, and silica as its chief constituents.[1] Since, however, no other mineral examined by him was found to contain as much as 0·01 per cent. of scandium,[2] there seemed to be little chance of finding this constituent

[1] W. Crookes, Phil. Trans. Roy. Soc. London, 1908, ser. A, vol. ccix, p. 17.

[2] A specimen of orthite has since been described as containing 0·8–1·0 per

in strüverite, with the comparatively small amount of material available for analysis; and the chemical examination of the mineral for this purpose led only to the indication of a possible trace.

Conclusions.

The mineral strüverite, as defined by Prior and Zambonini (loc. cit.), has now been found in three widely separated localities, viz. (1) at Craveggia, in northern Piedmont, Italy; (2) in the Etta mine, Black Hills, South Dakota, U.S.A.; (3) Perak, Malay Peninsula, and it is rather remarkable, in view of the probable nature of the mineral, that the composition, as seen from the analyses given below, should show such slight variations.

	Piedmont (Prior).	South Dakota (Wells).	Perak (Johnstone).
TiO_2	41·20	47·8	45·74
Ta_2O_5	46·96[1]	34·8	35·96
Nb_2O_5		6·2	6·90
FeO	11·38	7·3	8·27
MnO	trace	—	trace
CaO	0·51	—	—
MgO	0·17	—	—
SnO_2	—	1·3	2·67
SiO_2	—	2·0	0·20
H_2O	—	0·4	0·50
	100·22	99·8	100·24
Sp. gr.	5·59	5·25	5·30

There is apparently no reasonable alternative to the view suggested by Prior that strüverite is a homogeneous isomorphous mixture, and that it is to be regarded as consisting essentially of a solid solution of tapiolite in rutile. On this assumption we may regard the ferrous oxide of the Perak specimen as combined with the niobic and tantalic

cent. of scandia; see R. J. Meyer, 'Ueber einen scandiumreichen Orthit aus Finnland und den Vorgang seiner Verwitterung,' Sitzungsber. Akad. Wiss. Berlin, 1911, pp. 379-384. Still more recently, a new mineral supposed to consist essentially of scandium silicate, and to contain about 37 per cent. of scandia, has been described; see J. Schetelig, 'Ueber Thortveitit, ein neues Mineral,' Centralblatt Min., 1911, pp. 721-726.

[1] This percentage was divided equally between the niobic and tantalic oxides to accord with a rough indication that these two oxides were present in approximately equal amounts. It seems highly probable, however (see below), that there was a substantial preponderance of tantalic oxide.

ides to form tapiolite, and treat the mineral as an isomorphous mixture rutile and tapiolite with small admixtures[1] of cassiterite, silica, and ater.

If now we calculate the separate volumes of these constituents,[2] add ese together and divide into the total mass, we get the value 5·33 for e density of the mineral, as against the value 5·30 actually found. eating the analysis of the South Dakota specimen in the same way, get the value of 5·17 for the calculated density of the mineral, as ainst the value 5·25 actually found. The approximation of the iculated to the observed values for the specific gravity may be garded as sufficiently close, in such a mineral, to be consistent with e solid-solution view.

On the same assumption, a consideration of the analysis of the edmont strüverite in relation to its specific gravity leads to an portant conclusion. The Piedmont specimen, as the analysis shows, as much purer than those from South Dakota and Perak. The state combination of the lime and magnesia is uncertain, but the amount is ry small. Neglecting these, and recalculating the analysis to 100 in rms of TiO_2 and $Fe(Ta, Nb)_2O_6$, we get :—

TiO_2	...	...	...	41·39 per cent.
$Fe(Ta, Nb)_2O_6$	...		...	58·61 „

now we take the specific gravity of this as being approximately 5·6, nd, assuming a specific gravity of 4·2 for the rutile, calculate what the ecific gravity of the $Fe(Ta, Nb)_2O_6$ constituent should be, we get the lue 7·3, which is approximately the specific gravity of a typical tapiolite, e. one containing only a few per cent. of niobic oxide. It appears, erefore, that the $Fe(Ta, Nb)_2O_6$ constituent of the Piedmont specimen ust be tapiolite; and if so, it follows that this specimen is really presentative of typical strüverite.

In stating the results of his analysis, Prior made it quite clear that had not adequate quantitative data for stating the exact relative rcentages of niobic and tantalic oxides present. These considerations not seem to have been taken into account by Hess and Wells, who c. cit.) have rather hastily concluded that the Piedmont specimen is t a typical strüverite. The evidence detailed above proves their nclusion to be incorrect, if we accept the view, to which they bscribe, that strüverite is an isomorphous mixture.

[1] The stannic oxide in the Perak specimen as analysed is present, in part at ast, as free cassiterite; and the silica as quartz granules.

[2] Assuming the following specific gravities: rutile 4·2, tapiolite 7·35, cassiterite 7·0, quartz 2·65, water 1.

A simple graphic method for determining extinction-angles in sections of biaxial crystals.

By H. G. Smith, A.R.C.S., B.Sc., F.G.S.

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[Read November 14, 1911.]

THE relationship between the optic axes and the vibration-directions in a section of a biaxial crystal was enunciated by Biot[1] in 1819, and may be stated as follows: The vibration-directions in any section of a biaxial crystal are given by the bisectors of the angles between the optic axes as projected on the plane of section.

Dr. Fletcher[2] and Mr. Harker[3] have elaborated the idea, but there appears to be room for a simpler presentment, more adapted to the needs of students, which does not involve the use of the optical indicatrix or the spherical projection.

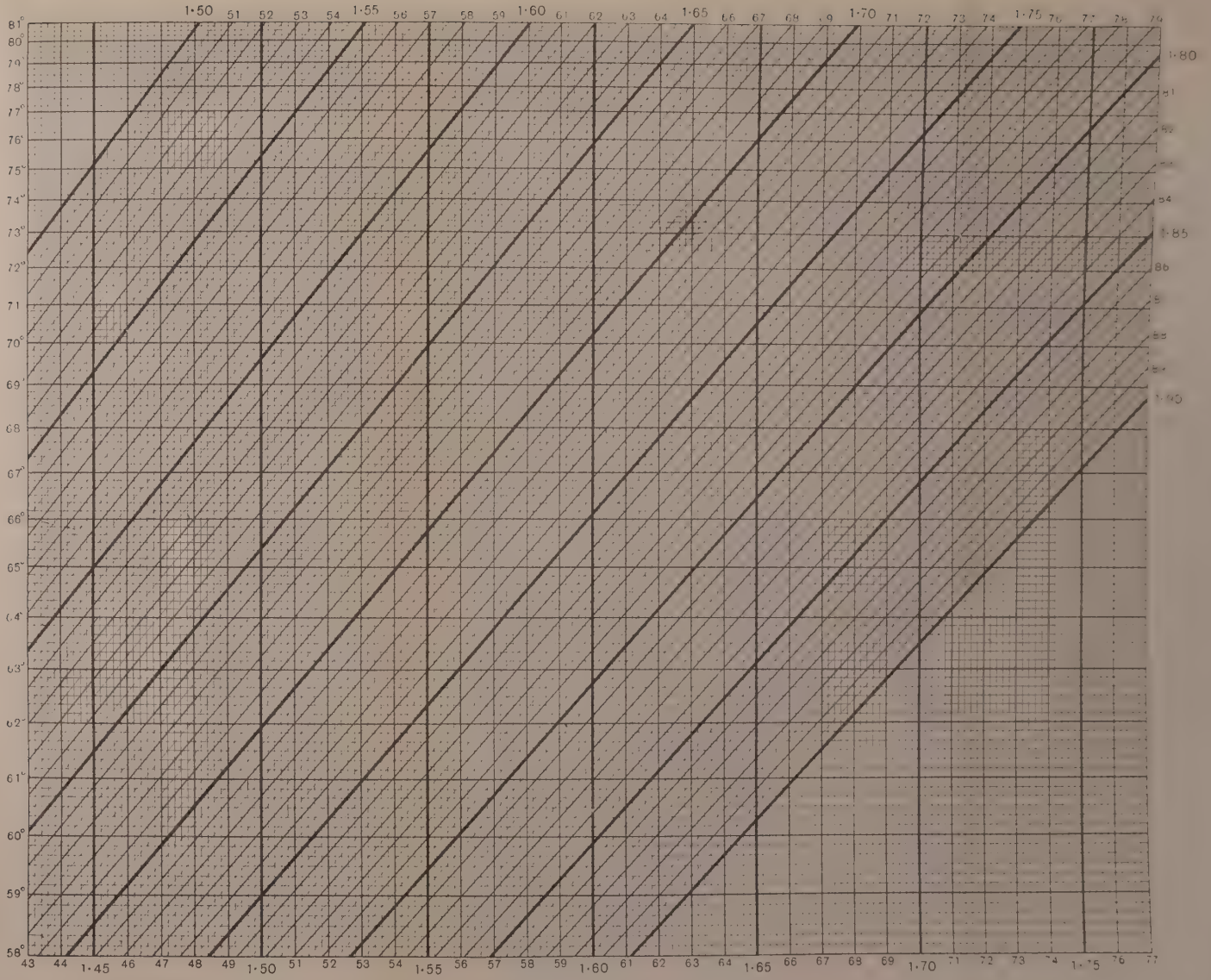
Largely because of its excellent cleavages, barytes was selected as a suitable mineral for experiment, and the following account relates: (1) to the actual experimental determination of the extinction-angles in a pyramidal section of that mineral; and (2) to the graphic method for obtaining the extinction-angles in such a section.

Experimental Determination.—Barytes cleaves into fragments bounded by faces of the prism and basal pinakoid. One of the rectangular edges of such a fragment was ground away so as to produce a pyramid face (*ABCD* in the figures) lying in the zone [110,001]. The inclination of this face to the basal pinakoid (the angle θ) was measured, and the fragment cemented, prepared face downwards, on a microscope-slip. Subsequent grinding produced a section showing two directions of cleavage, the inclination of which depends on the value of θ. One set of

[1] J. B. Biot, 'Sur les lois générales de la double réfraction et de la polarisation dans les corps régulièrement cristallisés,' Mém. Acad. Royale des Sci., Institut de France, 1820, vol. iii (année 1818), pp. 177–384.

[2] L. Fletcher, 'The optical indicatrix and the transmission of light in crystals,' Mineralogical Magazine, 1891, vol. ix, pp. 278–388 (see p. 341).

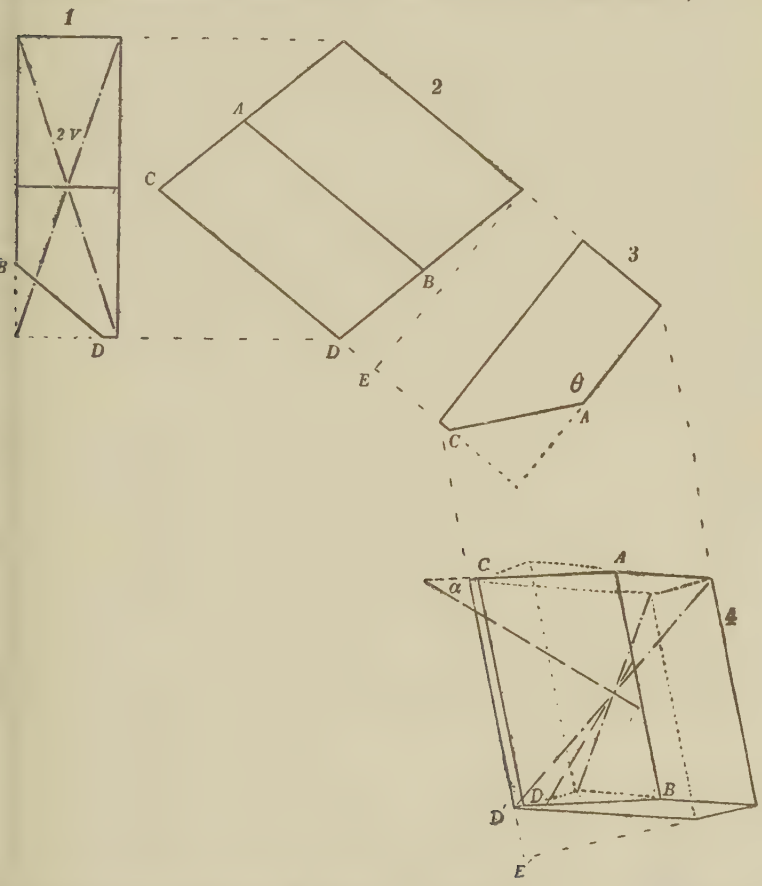
[3] A. Harker, 'Extinction-angles in cleavage-flakes,' Mineralogical Magazine, 1893, vol. x, pp. 239–240.



Index of solid.

A. Hutchinson: Total-Reflection Diagram.

cleavage-cracks is produced by the cleavages parallel to (110) and (001), and those of the other set by the cleavage parallel to the prism faces (1$\bar{1}$0) and ($\bar{1}$10) not lying in the zone [110,001]. As the latter were the sharper, they were chosen as the datum-line from which the extinctions were measured (the angle α in the accompanying diagram). The



ibration-directions were distinguished as 'fast' and 'slow' by means of quartz-wedge.

The Graphic Method.—The principle of this method consists in obtaining an accurate orthographic projection on the plane of the section (fig. 4). For the construction of this it is necessary first to draw projections on (010) (fig. 1), on (001) (fig. 2), and on the zone-plane [110,001] (fig. 3).

As (010) is the optic axial plane, the optic axes are here inserted with the true inclination 2V (= $37\frac{1}{2}°$ in barytes), and the dimensions of the rectangle are so chosen as to allow the optic axes to emerge from the corners (fig. 1). In the projection on the zone-plane, the true value of the measured angle θ is inserted (fig. 3). In fig. 2, the perpendicular from an acute corner of the rhomb on to the side CD gives the distance DE used in fig. 4, $D'E'$ being made equal to DE. The projection (fig. 4) on the artificially-prepared pyramidal face $ABCD$ is obtained by projecting at right angles to the trace of this face shown in fig. 3. Here CD and $D'E'$ appear in their true length, and these dimensions are taken from fig. 2. A line drawn from E' perpendicular to CD gives a third corner of the projected basal plane and the direction of the prism-edges, and the rest of the figure is easily constructed. The projected optic axes are inserted by joining the corners corresponding to those in fig. 1, and their angles are bisected. The bisectors should then be inclined to the traces of the prismatic cleavage (that parallel to $(1\bar{1}0)$ and $(\bar{1}10)$) at angles agreeing with the extinction-angles (α and $90°-\alpha$) obtained experimentally.

The 'fast' and 'slow' vibration-directions may be distinguished by considering their situation with regard to the bisectrices; the bisector of the acute angle in most of the sections approximately coincides with what would be the projection of the acute bisectrix, and, barytes having a positive sign, this must be the 'slow' vibration-direction.

The results compared below include those obtained by the graphic method, the experimental determinations, and those calculated by a modification of Harker's method. The angles are given to the nearest quarter of a degree, and represent the inclination (α) of the 'fast' vibration-direction with the prismatic cleavage for different values of θ.

θ.	α Graphic Method.	α Observed.	α Calculated.
$108\frac{1}{2}°$	$13\frac{1}{2}°$	$14°$	$13\frac{3}{4}°$
121	$22\frac{1}{2}$	23	22
$134\frac{1}{4}$	$29\frac{3}{4}$	29	$29\frac{3}{4}$
$136\frac{1}{4}$	31	31	31
142	$32\frac{1}{2}$	32	$32\frac{3}{4}$
$150\frac{1}{4}$	$35\frac{1}{2}$	$35\frac{1}{2}$	$35\frac{3}{4}$

The graphic method herein described is capable of general application to biaxial crystals, wherever the crystallographic orientation of the section and the optic orientation of the crystal are known. Its principle consists in obtaining an orthographic projection on the plane of section,

ıd bisecting the optic axial angles so projected. At least three drawings :e necessary :

(*a*) A projection on the optic axial plane, where the optic axes are inserted with the inclination 2V.

(*b*) A projection on the plane of the zone containing the prepared face and that from which its inclination is measured. Here the angle θ is inserted.

(*c*) A projection on the plane of section. This is obtained from (*b*) by projection at right angles to the trace of the prepared face.

In the case of barytes an additional projection—that on (001)—was ecessary in order to obtain the dimension *DE*. With similar simple ıodifications to meet special cases, the method gives a view of the crystal ı the required position ; the bisectors of the projected optic axial angles hen give the vibration-directions ; and the inclinations of these with ome datum-line give the extinction-angles.

A diagram for use with the total-reflectometer.

(*With Plate VIII.*)

By A. Hutchinson, M.A., Ph.D.

Demonstrator of Mineralogy in the University of Cambridge.

[Read November 14, 1911.]

THE accompanying diagram (Plate VIII) has been prepared in order to facilitate the determination of indices of refraction with the Kohlrausch total-reflectometer,[1] by affording a means of rapidly working out the results by a graphical method.

The Kohlrausch instrument enables measurements to be made of the critical angle θ, at which total reflection begins, when monochromatic light is reflected at the plane surface of a solid of refractive index μ immersed in a liquid of higher refractive index μ'. The relation between these quantities is given by the equation

$$\frac{\mu}{\mu'} = \sin\theta.$$

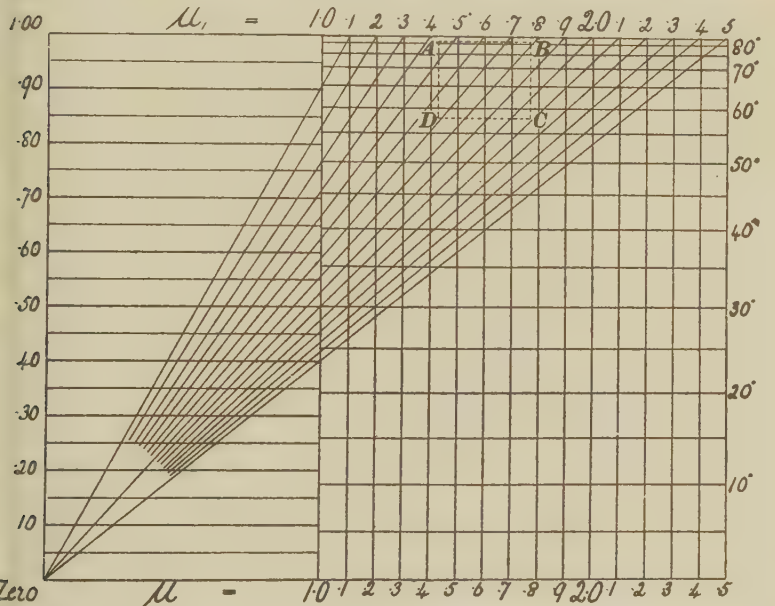
For any given value of μ', the relation between μ and θ may be expressed graphically by plotting as ordinates the values of θ in degrees, and as abscissae the corresponding values of μ; it is, in fact, given by a sine curve passing through the origin, and terminating on the line of 90° at the point corresponding to the value of μ', for when μ is zero, $\sin\theta$ and θ are also zero, and when $\mu = \mu'$, $\sin\theta = 1$, and $\theta = 90°$.

A diagram can, therefore, be made by constructing a series of these curves for different values of μ', by the aid of which any one of the three quantities μ, μ', θ, can be determined by inspection, if two of them are known. It is, however, difficult to draw these sine curves with the requisite degree of accuracy, and the calculation and plotting of the points necessary to determine them involves much labour. It is, therefore, better to use the values of the natural sines as ordinates rather than the angles themselves. When this is done, the curves become a series of straight lines radiating from the origin and intersecting the upper

[1] Compare A. Hutchinson, 'A universal goniometer,' Mineralogical Magazine, 1911, vol. xvi, pp. 100–108.

boundary of the diagram at points corresponding to the successive values of μ'.

The text-figure annexed shows a diagram constructed in this manner. On inspection it will readily be seen that only a small portion of it has any practical significance for our purpose. On the one hand, we do not require to determine indices of refraction lower than that of fluorite (1·433), and, on the other hand, the application of the method is limited to substances having a refractive index not greater than 1·83, owing to the non-existence of suitable liquids possessing refractive



ndices above the latter figure.[1] The only part of the diagram actually eeded in practical work is the area *ABCD*, bounded by the dotted ines. Plate VIII represents this area drawn to a scale about 17½ times s great as that employed in the text-figure. This amount of enlargement nables readings of θ to be made direct to 10′ over the greater part of he diagram and by estimation to 1′ or 2′; from 75° onwards the direct eading is to 15′.

[1] The possibility of preparing liquids of higher refractive index than 1·88 has ecently been indicated by F. E. Wright, 'The methods of petrographic-micro-copic research' (Carnegie Institution of Washington, Publication No. 158), 911, p. 98.

The values of μ extend from 1·430 to 1·770, and thus include fluorite and corundum within their range. They can be read direct to 2 units of the third decimal place, and by estimation to 5 units of the fourth place or less, a degree of accuracy quite sufficient for many purposes. The curves are drawn for values of μ' ranging from 1·50 to 1·90; they thus include the index of refraction (1·89 about) of the highly refractive glass used for the hemisphere of the Abbe-Czapski total-reflectometer. The values can be read direct to 5 units of the third decimal place and by estimation to one unit..

In constructing the diagram, the values of θ and μ were first marked off, the positions at which the diagonal lines would cut the boundaries were then calculated, and the lines ruled in.

To illustrate the application of the diagram we will in conclusion give one example of each of the three cases which may arise:

Given $\mu = 1{\cdot}5105$, $\mu' = 1{\cdot}6545$;

θ by diagram $= 65° 55'$, calculated $65° 55'$.

„ $\mu = 1{\cdot}5105$, $\theta = 59° 13'$;

μ' by diagram $= 1{\cdot}7590$, calculated 1·7582.

„ $\mu' = 1{\cdot}7830$, $\theta = 65° 22'$;

μ by diagram $= 1{\cdot}6205$, calculated 1·6207.

In all three cases the calculated figures were worked out after those obtained from the diagram had been read.

On the identity of Neocolemanite with Colemanite.

By A. Hutchinson, M.A., Ph.D.
Demonstrator of Mineralogy in the University of Cambridge.

[Read January 23, 1912.]

THE beautiful crystals of colemanite from the Death Valley, Inyo County, and from the Calico district, San Bernardino County, California, were described almost simultaneously in the autumn of 1884 by several different observers.[1] The most complete examination we owe to Jackson, who identified forty-two forms and determined the axial ratios which are usually accepted for the mineral, namely, $a:b:c = 0{\cdot}774843:1:0{\cdot}540998:\beta = 110°\ 9'\ 15''$. Very similar values for these constants were adopted by Hiortdahl and by vom Rath.

In 1902 Eakle[2] published a full account of the measurements made by him with the two-circle goniometer on a number of good crystals, some of which had already been examined by Jackson. In order to render two-circle methods more intelligible to his readers he appended to his description of the crystals an account of the principles underlying this mode of treatment, with full examples of the necessary calculations. As the result of this work, thirteen new forms were added to the list, making fifty-five in all, and the values of the position-angles ϕ and ρ were tabulated for forty-seven of these. The crystals were set up with the zone-axis of the prism-zone, [100,010], parallel to the axis of the vertical circle, and the following axial ratios[3] were adopted, $a:b:c = 0{\cdot}7768:1:0{\cdot}5430;\ \beta = 110°\ 7'$.

In 1911 Eakle[4] described a borate from Lang, Los Angeles County,

[1] A. W. Jackson, Bull. Calif. Acad. Sciences, 1885, No. 2, pp. 2–36, and 1886, No. 4, 358–365; T. Hiortdahl, Zeits. Kryst. Min., 1885, vol. x, pp. 25–31; C. Bodewig and G. vom Rath, ibid., pp. 179–186; A. Arzruni, ibid., 272–276.

[2] A. S. Eakle, Univ. Calif. Publ. Bull. Dept. Geol., 1902, vol. iii, pp. 31–49.

[3] All the angles of colemanite quoted in this paper have been computed from these constants.

[4] A. S. Eakle, 'Neocolemanite, a variety of colemanite, and howlite from Lang, Los Angeles County, California,' Univ. Calif. Publ. Bull. Dept. Geol., 1911, vol. vi, pp. 179–189.

California, of which he says: 'The borate is known as colemanite, and in its chemical composition and general physical properties it agrees with the colemanite from the Death Valley and Calico district, but in its optical and crystallographic properties it is somewhat different, so the name *neocolemanite* is proposed to distinguish it as a variety of colemanite.'

It would appear, however, that Eakle's measurements are capable of a different interpretation to that put upon them by him, and it is the object of this communication to show that by a change in the orientation adopted for the crystals the properties of neocolemanite can be brought into complete harmony with those of colemanite. In order to demon-

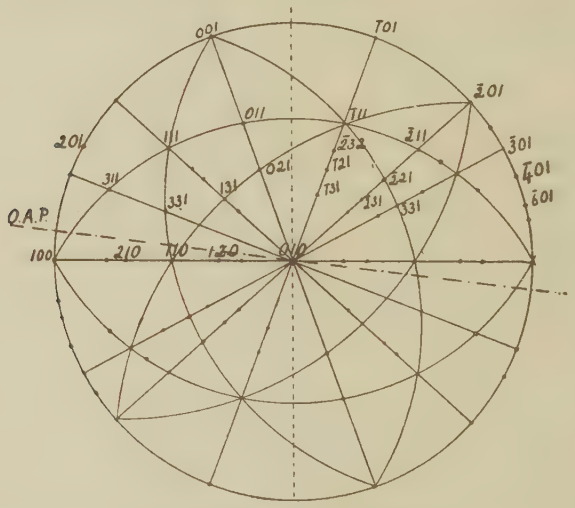


Fig. 1.—Stereogram of Colemanite.

strate this identity it will be necessary to give first a brief description of the crystallography of colemanite and of neocolemanite, and then to proceed to a comparison of the two.

Colemanite.

The poles of a number of the fifty-five forms observed on this mineral are marked on the accompanying stereogram (fig. 1), and the corresponding indices are inscribed against one pole of each of the forms of common occurrence, as well as of one form {331} which is but rarely met with. The projection has been made on the plane of symmetry, as this position is best adapted for exhibiting the interesting zonal relations of the substance.

It will be observed in the first place that the faces (001) and (1̄01) are ɔout equally inclined to the vertical axis, and that the angles (010):)11) = 62° 59′ and (010) : (021) = 44° 26½′ are approximately the same (010) : (1̄11) = 63° 4½′ and (010) : (1̄21) = 44° 33′. This relation as observed and commented on by all previous workers and led to the ggestion that the crystals might be referred to a set of nearly rect- gular axes.

Another relation, which appears, however, to have escaped attention herto, is the similarity of the angles (001) : (100) = 69° 53′ and 01) : (2̄01) = 68° 25′, coupled with the approximate equality of the gles measured in the two zones [010, 100] and [010, 2̄01]. Thus we

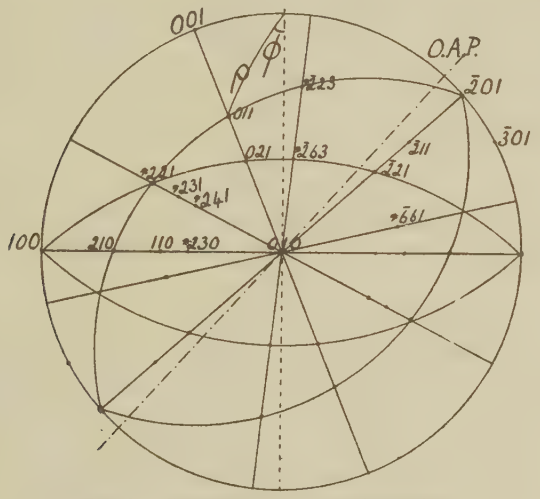


Fig. 2.—Stereogram of Neocolemanite.

ve (010) : (110) = 53° 53½′ and (010) : (210) = 69° 58′, while (010): 21) = 54° 9′ and (010) : (2̄11) = 70° 8½′. This similarity suggests other possible arrangement of nearly rectangular axes, (40 1̄) ing taken as (100), but owing to the resulting complexity of the dices such a selection offers no advantages. Further, it will be noticed at while the face (201) is present there are no other forms developed the zone [010, 201].

The mineral has an excellent cleavage parallel to the plane of sym- etry, (010), and also possesses a less perfect, but distinct, cleavage rallel to (001). The plane of the optic axes is perpendicular to the ane of symmetry and makes an angle of approximately 84° with the

vertical axis in the obtuse axial angle, its trace, shown by a broken line in fig. 1, being coincident with the acute bisectrix.

Neocolemanite.

On the crystals from Lang, Los Angeles County, Eakle observed eighteen forms, of which eleven were identified with known forms of colemanite, but seven were described as new. The positions of the whole of these forms are shown on the stereogram[1] (fig. 2), the indices of the seven new ones being prefixed by an asterisk.

If now we compare the development of these crystals with those of colemanite we notice at once certain very characteristic differences. In the first place the zone [201,010], which, as we have seen, is not developed in colemanite, is well represented in neocolemanite by the three new forms {221}, {231}, and {241}. Another new zone contains the forms {223} and {263}. On the other hand, the important zones [010,101] and [010,$\bar{1}$01] of colemanite are unrepresented in neocolemanite.

Ten good crystals were measured by Eakle on the two-circle goniometer, and the angles he observed are quoted in the following table (table I), together with the calculated angles given by him in 1902 for the eleven known forms.

On comparing the two sets of values it will be seen that a moderate degree of concordance prevails except in the case of the faces (001), (011), and (021). For (001) the value of ρ is considerably too great, while both ϕ and ρ lie well outside the limits of experimental error for the other two forms. On this point Eakle writes as follows: 'It was evident from the first crystal measured that the angles ϕ and ρ for the clinodomes and base were greater than those for colemanite, indicating that the vertical axis was longer and the forms steeper. This variation was constant for all crystals, and the lowest values of ϕ and ρ were higher than the greatest values for the corresponding faces on colemanite.' This discrepancy led Eakle to assign to neocolemanite the axial ratios, $a:b:c = 0{\cdot}7771:1:0{\cdot}5492$; $\beta = 111° 40'$; and if these constants are adopted, the calculated values of ϕ and ρ agree very closely indeed with those determined by measurement.

[1] The stereograms, figs. 1 and 2, are on the same scale and have been reduced from accurate projections 20 cm. in diameter. Since the plane of projection is the plane of symmetry, each dot may be taken to represent two faces, one in the northern hemisphere and one vertically below it in the southern.

Table I.

Form.	Neocolemanite. Measured.		Colemanite. Calculated.	
	ϕ	ρ	ϕ	ρ
001	90° 00′	21° 40′	90° 00′	20° 07′
010	0 00	90 00	0 00	90 00
100	89 58	90 00	90 00	90 00
110	54 09	90 00	53 53	90 00
210	70 08	90 00	69 58	90 00
230	42 41	90 00	—	—
021	19 58	49 22	18 38	48 54
011	35 53	34 07	34 00	33 13
301	90 00	62 00	90 00	61 49
201	90 00	48 15	90 00	48 18
241	41 10	71 09	—	—
281	49 20	68 25	—	—
221	60 12	65 43	—	—
661	51 32	79 39	—	—
221	45 52	57 31	45 56	57 22
223	18 47	20 50	—	—
263	5 24	47 47	—	—
211	63 59	51 21	64 11	51 16

Another important difference between the two substances is the position of the plane of the optic axes, which in neocolemanite is inclined at an angle of about 42° to the vertical axis in the acute axial angle. With these exceptions the properties of neocolemanite agree with those of colemanite, and Eakle concludes his account of the former mineral with the remark: 'The analysis of the mineral shows that it does not differ from colemanite in composition, so the indicated morphotropy in the vertical direction is not due to a chemical replacement or change. The variety is simply an allotropic modification of colemanite brought about by a possible difference in the mode of crystallization.'

Identity of Neocolemanite and Colemanite.

That a mineral so beautifully crystallized and so definite in composition as colemanite should exist in two forms, at once so similar in many respects and so different in others, appeared to the writer a phenomenon worthy of some attention, for it seemed not impossible that a change in the orientation of the crystals might perhaps bring the properties of the two substances into harmony. This idea had evidently been present to Eakle, for he says: 'If the neocolemanite is reversed in position so that

all the positive forms become negative and vice versa, then the readings would correspond closer to those for forms on colemanite . . . .' He rightly concludes, however, that this suggestion cannot be entertained, for he adds: 'the two minerals have a similar basal cleavage, and it was by this cleavage that the crystals were oriented.'

In offering an alternative explanation we must, therefore, bear in mind that there can be no doubt as to the correct identification of the zone [010, 001] in the two minerals, and we have accordingly to face the difficulty presented by the great discrepancies in the values of the angles ϕ and ρ for the faces (011) and (021). This difficulty is, however, more apparent than real, and depends on the circumstance that the two-circle measurements given by Eakle, though perfectly accurate in themselves, do not exhibit the important zonal relations of the crystals, but indeed only too effectually conceal them! Taking, on the one hand, the measured angles ϕ and ρ observed on neocolemanite, and, on the other hand, the axial ratios of colemanite adopted by Eakle, we will calculate the angles (010):(011) and (010):(021) for both minerals. The result is as follows:

Neocolemanite, $(010):(011) = 62° 58'$; $(010):(021) = 44° 30'$.

Colemanite, $(010):(011) = 62° 59'$; $(010):(021) = 44° 26\frac{1}{2}'$.

The agreement is excellent, and disposes of the view that there is any abnormal angular development in this zone.

Further, since the neocolemanite angle $(001):(100) = 68° 20'$ is very near to the colemanite angle $(001):(\bar{2}01) = 68° 25'$, the idea suggests itself that an explanation of the anomalous properties of the former substance is to be sought in the great similarity of the two zones of colemanite [010, 100] and [010, $\bar{2}$01]. This similarity has already been remarked upon above, and it is obvious that it may readily become a dangerous source of confusion.

To test this view, let us begin with a crystal of neocolemanite in the position of fig. 2, and let us rotate it through 180° about the normal to the (001) face. When this is done the face (100) (neocolemanite) comes into the position occupied by the face ($\bar{2}$01) (colemanite); (010) and (0$\bar{1}$0) change places, while the forms {210}, {110}, and {230} become coincident with {$\bar{2}$11}, {22$\bar{1}$}, and {$\bar{2}$31} respectively. At the same time, the forms {221}, {231}, and {241} (neocolemanite) fall into the positions occupied by {$\bar{1}$11}, {$\bar{2}$32}, and {$\bar{1}$21} (colemanite); {$\bar{2}$23} and {$\bar{2}$63} become {111} and {131}; {$\bar{2}$11} and {$\bar{2}$21} become {210} and {110}; the face ($\bar{3}$01) becomes (60$\bar{1}$); and finally {$\bar{6}$61} becomes {$\bar{3}$31}.

This identity can be convincingly demonstrated by means of the two stereograms, for if a copy of fig. 2 be made on tracing paper and the paper be then reversed, back to front, and applied to fig. 1, so that the poles of (001) are coincident, the truth of the above statements can easily be verified. Further, it will be seen that the new orientation brings the optic axial plane of neocolemanite into coincidence with that of colemanite, an inclination to the vertical of 42° in the acute axial angle of neocolemanite being the equivalent of an inclination of 83° 47′ to the vertical axis in the obtuse axial angle of colemanite.

Table II.

Neocolemanite.				Colemanite.				
		Angle on 010.	Angle on 001.	Angle on 010.	Angle on 001.			
b	010	—	90° 00′	—	90° 00′	010	*b*	common
c	001	90° 00′	—	90° 00′	—	001	*c*	,,
κ	011	62 58	27 2	62 59	27 1	011	*κ*	,,
a	021	44 30	45 30	44 26½	45 33½	021	*a*	,,
h	$\bar{2}01$	90 00	69 55	90 00	69 53	100	*a*	,,
o	$\bar{2}11$	69 58	71 11	69 58	71 9	210	*t*	,,
v	$\bar{2}21$	54 2	73 52	53 53½	73 52	110	*m*	,,
*ϖ	$\bar{2}23$	70 5½	33 50	70 2	33 49	111	*β*	,,
*b	$\bar{2}63$	42 30	53 21	42 32	53 18½	131	*ω*	frequent
*σ	221	63 4	47 39	63 4½	47 34	$\bar{1}11$	*y*	common
*τ	231	52 42	53 3	52 42	52 59½	$\bar{2}32$	*r*	frequent
*ε	241	44 34	57 58½	44 33	57 56	$\bar{1}21$	*d*	common
a	100	89 58	68 20	90 00	68 25	$\bar{2}01$	*h*	,,
t	210	70 8	69 41	70 8½	69 45½	$\bar{2}11$	*o*	,,
m	110	54 9	72 35	54 9	72 39	$\bar{2}21$	*v*	,,
*ι	230	42 41	75 30	42 42	75 33	$\bar{2}31$	*ϵ*	frequent
*q	$66\bar{1}$	52 16	83 15½	52 25½	83 37	$\bar{3}31$	*q*	rare
W	$30\bar{1}$	90 00	96 20	90 00	96 24½	$\bar{3}01$	*U*	frequent

* Indicates the new forms.

To further demonstrate the correctness of this explanation, the angles which all the faces of neocolemanite make with the two cleavage-planes (010) and (001) have been calculated from the observed values of ϕ and ρ published by Eakle; and these have been tabulated for comparison with the angles made with the same two cleavage-planes, by those faces of colemanite with which the neocolemanite faces become coincident when the crystals of the latter mineral are rotated about the normal to (001) in the manner described above. The results of these calculations are given in table II, in which are arranged: (i) the letters and indices assigned to the forms of neocolemanite, together with the angles made by

the faces of these forms with the planes (010) and (001) respectively (ii) the letters, indices, and angles of the forms of colemanite with which the neocolemanite forms are identical; (iii) a statement as to the relative frequency of occurrence of the various forms of colemanite taken from the writings of Eakle and Jackson.

A glance at the table shows an extraordinary degree of concordance between the two sets of figures. In but three instances does the divergence exceed 5′, and the most pronounced discrepancy occurs, as it happens, in the case of the form q (colemanite), the only one of the whole eighteen which is of rare occurrence, and for which the tabulated values of ϕ and ρ represent but one observation. With this exception the new forms of neocolemanite are seen to be planes of common occurrence on colemanite and to exhibit identical angular relations—an indirect but valuable testimony to the accuracy of Eakle's goniometric observations.

Conclusions.

The results of this investigation may then be briefly summarized as follows:

1. The crystallographic and optical properties of neocolemanite can be brought into harmony with those of colemanite by a change in the orientation of the crystals.

2. This is brought about by rotating the neocolemanite crystal through 180° about the normal to the cleavage-plane (001).

3. This rotation brings the new forms {221}, {231}, {241}, {$\bar{2}$23}, {$\bar{2}$63}, {66$\bar{1}$}, and {230} into coincidence with well-known forms of colemanite {$\bar{1}$11}, {$\bar{2}$32}, {$\bar{1}$21}, {111}, {131}, {331}, and {$\bar{2}$31}.

4. At the same time the optic axial planes also become coincident.

5. The name neocolemanite and the special axial ratios assigned to it are therefore unnecessary.

NOTES.

The following deaths have to be recorded:

Salvador Calderón y Arana (1851–1911), Professor of Mineralogy in the Central University of Spain and Chief of the section of Mineralogy in the Museum of Natural Sciences at Madrid, was previously (1884–1895) Professor of Natural History in the University of Sevilla. In 1905 he was elected president of the Real Sociedad Española de Historia Natural, of which society he had for many years previously acted as secretary; and recently (1909) he was elected an honorary member of the Mineralogical Society. Calderón's first work was on the volcanic rocks of the Canary Islands, and the majority of his later papers related to the geology and minerals of Spain. His Mineralogy of Spain, first published in German in conjunction with C. A. Tenne in 1902, was much enlarged in the Spanish edition of 1910 (reviewed in this volume, p. 72).

A detailed biographical notice, with bibliography and portrait, has been given by E. Hernández-Pacheco, Bol. R. Soc. Españ. Hist. Nat., 1911, vol. xi, pp. 405–445.

Eugen Hussak (1856–1911) was born on March 10, 1856, at Wildon near Graz in Styria, and died on September 5, 1911, at Caldas in Brazil. He studied at Graz, Vienna, and Leipzig, taking his degree in 1878 at Leipzig, where for a time he acted as assistant to Professor Zirkel. During 1882–5 he was Dozent in Mineralogy and Geology in the University of Graz, at the same time acting as a voluntary assistant on the Austrian Geological Survey; and in 1885–8 he was assistant to Professor Laspeyres at Bonn. In 1888 he sought a fresh opening by accepting the post of mineralogist and assistant geologist on the then newly-established 'Commissão Geographica e Geologica do Estado de São Paulo', becoming chief of the geological section in 1905. In 1908 he took up a similar appointment on the new 'Serviço Geologico e Mineralogico do Brazil' with head-quarters at Rio de Janeiro.

Most of Dr. Hussak's earlier papers were of a petrographical character; but later he worked assiduously at Brazilian minerals, several valuable papers descriptive of new species having been contributed by

him, in conjunction with Dr. G. T. Prior, to the pages of this Magazine. Since 1893 he had been an ordinary member of our Society. His book on rock-forming minerals, first published in 1885, was translated into English and passed through two editions in America.

A bibliography of his works, extending to sixty-five titles, has appeared in the 'Jornal do Commercio' of Rio de Janeiro.

Auguste Michel Lévy (1844–1911), Director of the Geological Survey of France, Inspector-General of Mines, and Professor in the Collège de France. He was a member of the Institute of France, and since 1898 an honorary member of our Society. In collaboration with F. A. Fouqué he produced the classical works 'Minéralogie micrographique: roches éruptives françaises' (1879), and 'Synthèse des minéraux et roches' (1882), and together with his son-in-law, Professor A. Lacroix, the well-known 'Les minéraux des roches' (1888). A later important mineralogical work is his 'Détermination des feldspaths' (1894–1904). His son, Albert Michel Lévy, carries on the petrographical work of the French survey on very much the same lines. (A brief notice has appeared in 'Nature', 1911, vol. lxxxvii, p. 524.)

Giorgio Spezia (1842–1911), Professor of Mineralogy and Director of the Mineralogical Museum in the University of Turin, was a member of the Lincei Academy at Rome; and ever since 1878 he had been an ordinary member of our Society. He died at Turin on November 10. He was best known by his contributions to chemical geology, in which he gave the results of various experiments made at high pressures and temperatures. The solubility of quartz in various aqueous solutions was determined under these conditions, and beautiful crystals of quartz were grown artificially. Some of his experiments had a bearing on the problems of rock-metamorphism.

Alfred Elis Törnebohm (1838–1911), formerly (1878–1897) Professor of Mineralogy and Geology in the Technical High School at Stockholm, and (1897–1906) Director of the Geological Survey of Sweden. His work, though mainly geological and petrographical in character, contained much of interest to mineralogists. He gave special attention to the iron-ores of Sweden; and in 1897 he published an important pamphlet 'Ueber die Petrographie des Portland-Cements' in which he proposed various names for the crystalline constituents of Portland-cement clinkers (this Magazine, vol. xii, p. 378). A detailed

account of his life and work has been given by A. G. Högbom (Geol. Mag., 1912, vol. ix, pp. 49–53, with portrait; Geol. För. Förh. Stockholm, 1912, vol. xxxiv, pp. 101–137, with bibliography and portrait).

Niels Viggo Ussing (1864–1911), Professor of Mineralogy and Director of the Mineralogical and Geological Museum in the University of Copenhagen since 1895. He had studied in Munich, Stockholm, and Heidelberg, and for some years was assistant in the Museum at Copenhagen. His principal work was on the interesting minerals of Greenland, to which country he took part in three expeditions. A long paper on the nepheline-syenites appeared in 1894, and his detailed account of the geology of the Julianehaab district was left in a sufficiently advanced stage for publication at the time of his death. He also wrote on the geology of Denmark. Never of very robust health, he died, after a long illness, on July 23. (For further particulars see O. B. Böggild, Centralblatt Min., 1911, pp. 529–530; and Geol. För. Förh. Stockholm, 1911, vol. xxxiii, pp. 475–478, with portrait.)

The first volume of a new annual publication entitled 'Fortschritte der Mineralogie, Kristallographie und Petrographie' appeared last year (Jena, 1911, pp. 290) under the auspices of the German Mineralogical Society (Deutsche Mineralogische Gesellschaft). This society, founded in 1908, holds its meetings in September in conjunction with the Gesellschaft Deutscher Naturforscher und Ärzte, a society which meets annually in different towns, in the same manner as the British Association; and abstracts of papers read before the mineralogical section appear in the 'Verhandlungen' of the parent society. The present volume, which has been edited by Professor G. Linck, contains a report of the proceedings of the meeting at Königsberg in September, 1910, under the presidency of Professor Max Bauer, the next succeeding president being Professor F. Becke. The membership of the new society had at that date already reached the satisfactory number of 158.[1] In addition to papers read at the meeting and themes brought forward for discussion, the volume includes reports on various special topics. Of the thirteen useful articles it contains we may mention: discussions on twin-crystals (by O. Mügge and F. Becke); a summary of our knowledge of the coloration of minerals (R. Brauns); a review of the literature of meteorites since 1900 (F. Berwerth); metamorphism (F. Becke); salt-petrography and metallography

[1] In February, 1912, the number was 238.

in relation to igneous rocks (F. Rinne); the phase-rule as applied to mineralogy (R. Marc).

'The Data of Geochemistry' by Professor F. W. Clarke, first published in 1908 as Bulletin No. 330 of the United States Geological Survey, has already reached a second edition (Bull. No. 491, 1911), with an increase from 716 to 782 pages. It contains an enormous amount of mineralogical information presented in an attractive manner and replete with valuable suggestions. There are numerous references to the literature, and, with the very complete index, the volume is extremely handy for purposes of consultation; and furthermore it appears to be always reliable.

'Directions for Laboratory Work in Optical Mineralogy' is the title of a pamphlet (36 pp., Wisconsin, 1911) published by the author, Alexander N. Winchell, Professor of Mineralogy and Petrology in the University of Wisconsin. It gives useful laboratory notes, briefly and clearly stated, and is intended for the use of students in conjunction with the same author's 'Elements of Optical Mineralogy'. Being printed on bad paper, the pamphlet is, however, not well suited for the rough and constant usage of the laboratory.

In celebration of the 70th birthday of Professor Paul von Groth, which will fall on June 23, 1913, it is proposed to publish a special volume of the 'Zeitschrift für Krystallographie und Mineralogie' containing papers from those of his numerous pupils and contributors who may wish so to join in doing honour to him. Arrangements for the preparation of the volume are now being made by Professor Erich Kaiser of Giessen (Südanlage 11).

In the meantime, Professor Groth may be congratulated on having reached the fiftieth volume of his 'Zeitschrift', which he founded thirty-five years ago (in 1877). This imposing row of volumes, which together with the four volumes of 'Repertorium' and 'General-Register' is in itself a working library, speaks much for his indefatigable industry and the long-continued support which he commands. Here we may also mention that last December Professor Groth was elected a Foreign Member of the Royal Society of London.

Honours likewise fall on mineralogists at home. The lists of New Year Honours include the name of Principal Miers as a new knight—

Sir Henry A. Miers; and at the recent Anniversary Meeting of the Geological Society Dr. L. Fletcher was awarded the Wollaston gold medal. Only shortly before, the same two past-presidents of our Society had received honorary degrees from foreign universities; the former that of D.Sc. at Christiania (and also recently at Sheffield) and the latter that of Ph.D. at Berlin. Still more recently our Secretary, Dr. G. T. Prior, has been elected a Fellow of the Royal Society.

An old collection of minerals, remarkable in containing many exceptionally fine and probably unique specimens, has recently come to light and been placed on the market. For many years it had remained hidden away in a suburb in the north of London, and its very existence was unknown to all but a few of the present generation of mineralogists. This collection was formed during two, and probably three, generations of the Walker family at Arnos Grove, Southgate; the last and most extensive collector being Mr. Isaac Walker[1] (1794–1853), a member of a firm of brewers, Taylor, Walker, and Co., of Limehouse. Being possessed of considerable means he was enabled to acquire the choicest and rarest specimens and to outbid other collectors, at a time when the formation of mineral collections was a fashionable hobby amongst persons of rank and culture. The majority of the best specimens were acquired between the years 1826 and 1847 from Henry Heuland, who by a cleverly-arranged series of public sales seems to have done much towards keeping alive the interest and rivalry of collectors. Many fine specimens came from the collection[2] of the dowager Countess of Aylesford (died 1832); and others were purchased at various sales, for example, that in 1827 of Sir Alexander Crichton's collection.

During that period scientific mineralogy was also ardently pursued in England by H. J. Brooke, T. Allan, T. Thomson, W. Phillips, A. Lévy, and many others. Mr. Isaac Walker left no records in the contemporary literature, and all we now find is a mention of his name as the donor of

[1] His father was John Walker and his grandfather Isaac Walker: the latter purchased the Arnos Grove estate about 1775. In a description of this estate, published in 1816, mention is made of a fine collection of minerals numbering nearly 4,000 specimens (E. W. Brayley, J. Britton, and J. N. Brewer, 'The Beauties of England and Wales,' 1816, vol. x, part 4, p. 709).

[2] Sold by H. Heuland in 1833-6. These specimens bear distinctive numbers corresponding to entries in the Lady Aylesford MS. catalogue, now in the British Museum (Mineral Department).

a specimen to the Turner collection.[1] Minerals appealed to him from the aesthetic rather than the scientific side. He preferred beautiful specimens of well-known species, and especially large and well-formed crystals. The collection contained some ten thousand specimens, amongst which are fine crystallized groups of chessylite from Chessy, topaz crystals from Brazil and Siberia, &c. After his death the collection passed from one to another of his seven, unmarried, sons, the celebrated cricketers, who have done their duty by the collection in keeping it well housed, and the specimens free from dust and damage.

Many fine specimens selected from this collection have fortunately been secured for the national collection of minerals, a considerable number having been generously presented by Mr. F. N. A. Fleischmann. These are now displayed in the recent addition case in the Mineral Gallery of the British Museum (Natural History) at South Kensington, where they may be admired by all comers, and where they will not run the danger of being forgotten and lost.

Another noteworthy collection of minerals, and one which we have omitted to note earlier in this Magazine, is that of the late Frederick Tendron, F.G.S., who died at Tunbridge Wells on April 14, 1910, at the age of 76. His collection was bequeathed to the Trustees of the British Museum with the request to select from it any specimens worthy of finding a place in the national collection. Being for many years the Chairman of the St. John del Rey Mining Company, which operates the Morro Velho and other gold mines in Brazil, he had ample opportunities of acquiring fine mineral specimens as well as ore samples for his collection; and in particular he possessed many large and finely-crystallized groups of pyrrhotite, albite, dolomite, chalybite, and quartz, as well as small crystals of the rare chalmersite, all from the noted Morro Velho mine. Amongst the pyrrhotites is a unique crystal measuring 14 cm. across. A series of well-crystallized nuggets of gold, probably from Australia, and various miscellaneous specimens, for example, diamond in 'cascalho' from Brazil and ruby in its matrix from Burma, were also selected for the British Museum. The residue of the collection passed to the Corporation of Tunbridge Wells to form the nucleus of a local museum.

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[1] A. Lévy's Catalogue, 1837, vol. iii, p. 221. The name 'J. Walker' there mentioned refers perhaps to the father.

REVIEWS.

Lehrbuch der Kristallphysik (mit Ausschluss der Kristalloptik). By Woldemar Voigt. Pp. xxiv + 964, with 213 text-figures and 1 table. (Leipzig and Berlin: B. G. Teubner. 1910. Price 30 marks.)

Prof. Voigt is widely known as one of the pioneers of the application of vectorial analysis to the study of the physical characters of a crystalline medium, and as the author of numerous papers on the subject that have appeared in various journals during the past thirty-six years, and no one is more obviously fitted to write a textbook on crystallographical physics. In this volume he gives a comprehensive survey of what is at the present time known of those properties of crystals, such as thermal dilation, elasticity, pyro- and piezo-electricity, and so on—which are passed over or only briefly alluded to in the ordinary textbooks; he has wisely excluded from his purview crystallographical optics, which is a subject large enough in itself to fill a volume, and is, moreover, adequately treated in other books.

Prof. Voigt views the subject from the theoretical standpoint, and the book will appeal mainly to mathematicians. The notation employed is not generally familiar, but the reader with a knowledge of the calculus will experience no difficulty in following the discussion, since the meaning of the notation is explained in the opening pages. The crystallographer would have liked fuller information regarding the not very extensive experimental work that has been done in this branch of physics; the results alone are given, and nothing is said about the methods adopted or the apparatus used. Further, recent work is not mentioned; for instance, no reference is made to Dr. Tutton's elaborate researches upon thermal dilation and elasticity. Except for this slight criticism, in the thoroughness with which it has been written the book leaves nothing to be desired, and as regards its scope it is unique; it is therefore likely to remain the standard textbook on this branch of physics for many years to come.

Die Kristallgruppen nebst ihren Beziehungen zu den Raumgittern. By E. Sommerfeldt. Pp. viii + 79, with 14 stereoscopic illustrations and 50 figures. (Dresden: Theodor Steinkopff. 1911. Price 3 marks.)

The geometrical theory of crystal structure presents many difficulties to the student approaching it for the first time; drawings on paper are of limited assistance to visualizing a complex distribution in three dimensions, and some writers have veiled the subject in a cloud of mysterious mathematical symbols. It becomes increasingly evident that crystallography is a branch of science of far-reaching importance, and some knowledge of it is required by workers in science who have had no profound mathematical training. An understanding of the theory of crystal structure is of great help to a proper appreciation of the properties of crystals.

For reasons such as these Prof. Sommerfeldt's little book will be welcomed. In it he gives in simple language an account of the leading features of the subject. He bases the discussion upon Bravais's space-lattices, and we may call attention to the excellent stereoscopic views of the models of the lattices in Prof. von Groth's laboratory at Munich, which will prove of great assistance to students who have not access to such models. From these simple distributions the reader passes on to more complex arrangements, which are grouped together according to the system to which they may be assigned, beginning with the lowest, the triclinic. In each section the characteristic polyhedral forms are first considered, and next the types of structure with rotational symmetry, including Sohncke's point-systems; the types resulting from the introduction of mirror-image symmetry are only lightly touched upon. Except in the case of the regular system, the text is elucidated by means of diagrams. For the first time, we believe, in any German textbook, Barlow's elegant theory of close-packing finds a place, and Prof. Sommerfeldt specifically dwells in the preface to the book upon its simplicity and importance.

The Mineral Kingdom. By Dr. R. Brauns. Translated, with additions, by L. J. Spencer. 4to, Parts 1 to 16, pp. 296, with 218 text-figures and 50 plates. (Stuttgart: Fritz Lehmann;[1] London: Williams & Norgate. 1908–1911. Price 2*s.* each part.)

First published in German in 1903–4, Dr. Brauns's work 'Das

[1] The publication of the remaining nine parts has been taken over by J. F. Schreiber of Esslingen a. N.

Mineralreich' has since appeared in three other European languages. We now have to welcome an English edition at the hands of the translator of Max Bauer's 'Edelsteinkunde'.

The work is not a textbook of mineralogy. Its abundance of accurate information is given simply and clearly, and the style of the book, aided by the beautiful coloured plates, is calculated to appeal not only to the mineralogist, but to all lovers of the beauties of Nature.

In order to give the beginner an insight into the underlying principles of crystallography, and perhaps to persuade him to seek a more thorough knowledge of these principles from textbooks, there has been written the General Part. This deals with the limits of the mineral kingdom, the distinction between minerals and rocks, the crystal-systems, varieties of crystal-growth, and, very briefly, with the physical and chemical characters of crystals.

The part dealing with the crystal-systems is well done and illustrated with good text-figures. The rhombohedral system is included in the hexagonal, and, while three systems of crystallographic notation are described, that of Naumann is selected as being more easily comprehended. The definition of a crystal as 'a body bounded on all sides by plane faces, and of such a form as is assumed by the substance itself' is open to criticism.

Part II deals with the Ores and their associates, with which are included sulphur and meteorites; it occupies 127 pages and is illustrated by 39 plates. The minerals used as ores of any one metal are all treated together, after which a brief account is given of the methods of working the ores, the applications of the metal, and in several cases its production in various countries during recent years. The principal characters whereby the different ores can be identified are clearly set forth, and abundant facts of an historical nature add greatly to the interest of the book. The classification here adopted is one to be strongly recommended in all books on minerals which aim at being of a popular nature, especially when, as is the case here, striking cases of polymorphism and of isomorphous series are pointed out and the real importance of crystal-form is carefully emphasized.

Part III is devoted to the Precious Stones and related minerals. It commences with several pages on the forms and methods of cutting and counterfeiting precious stones, and some interesting notes of an historical character. The descriptions of the several minerals consist of crystallographic details, the chief optical characters, and methods of identification, and an account of the history and occurrences of the stones.

The coloured plates are a great feature of the book, and the specimens figured, being taken from the best German collections, are of great interest.

The work of translation has been done in a manner which leaves nothing to be desired, and the numerous additions in the text and in the tables of analyses and annual productions of metals have done much to bring the book up to date.

W. C. S.